US Army Corps of Engineers
Waterways Experiment Station

Wetlands Research Program Technical Report WRP-RE-11

Cache Slough/Yolo Bypass Ecosystem Monitoring Study to Determine Wetland Mitigation Success

by Michelle Stevens, Eliska Rejmankova



October 1995 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

Technical Report WRP-RE-11
October 1995

Cache Slough/Yolo Bypass Ecosystem Monitoring Study to Determine Wetland Mitigation Success

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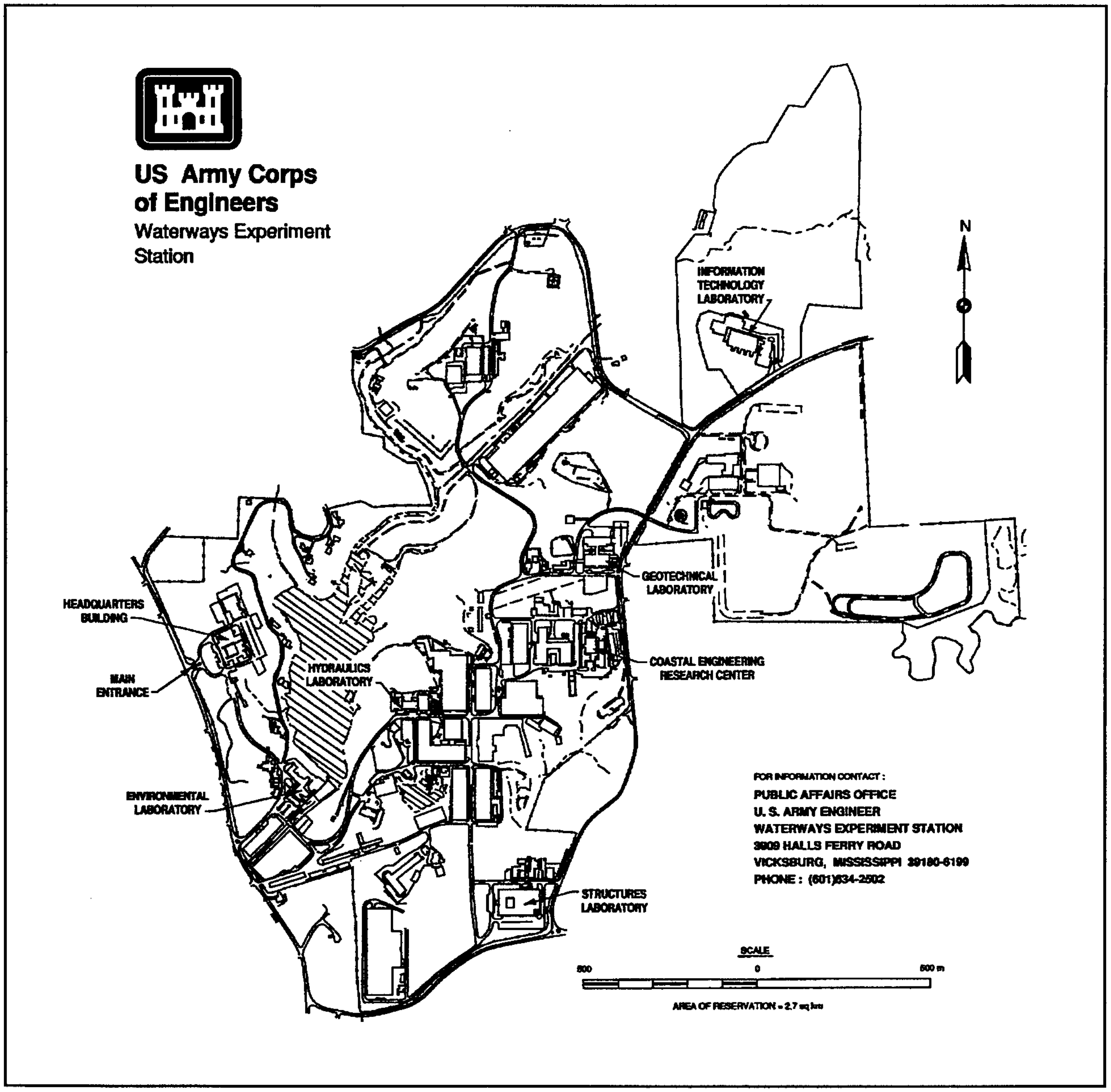
Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Stevens, Michelle L.

Cache slough/yolo bypass ecosystem monitoring study to determine wetland mitigation success / by Michelle Stevens, Eliska Rejmankova ; prepared for U.S. Army Corps of Engineers.

121 p. : ill. ; 28 cm. -- (Technical report ; WRP-RE-11) (Wetlands Research Program technical report ; WRP-RE-11)

Includes bibliographic references.

1. Ecosystem management -- California. 2. Wetland conservation -- California. 3. Species -- Composition -- Measurement. I. Rejmankova, Eliska. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Wetlands Research Program (U.S.) V. Title. VI. Series: Wetlands Research Program technical report ; WRP-RE-11. VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; WRP-RE-11.

TA7 W34 no.WRP-RE-11

Corps of Engineers Research Report Summary, October 1995

Mitigated Riparian Wetlands Monitoring

Cache Slough/Yolo Bypass Ecosystem Monitoring Study to Determine Wetland Mitigation Success (TR WRP-RE-11)

ISSUE:

Although considerable research work has been conducted in the field of wetland restoration and creation, there are a number of wetland types and geographic regions for which not enough information is in hand to accomplish this work with predictable success. Continued data collection and evaluation are necessary to provide the best technology for restoration and creation, including comparison of these man-made wetland systems to natural wetland systems.

RESEARCH:

The Cache Slough mitigation area was designed and constructed by the U.S. Army Corps of Engineers to mitigate impacts to fish and wildlife habitats from the Sacramento River Bank Protection Project. This study was designed to evaluate and analyze mitigation success in relation to project goals and objectives, in comparison to adjacent, western riparian reference areas. Eight permanent transects with associated permanent vegetation quadrats were established around the perimeter of the open-water component of the mitigation area. Species composition, relative abundance, and frequency were measured.

SUMMARY:

This report provides baseline information on site conditions, vegetation species composition, soils, water quality, and hydrology at both the mitigation and reference areas. The information presented can serve as a model for design of baseline assessments for western riparian wetlands.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Authors:

Michelle Stevens and Eliska Rejmankova are on the staff of the Botany Department at the University of California, Davis. Point of contact at WES is Dr. Mary C. Landin, Research Biologist, phone (601) 634-2942.

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Wetland Restoration, Protection, and Establishment of Wetlands Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32761 for which Dr. Mary C. Landin, U.S. Army Engineer Waterways Experiment Station (WES), was the Technical Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work.

Mr. Dave Mathis was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch served as the WRP Technical Monitor's Representative; Dr. Russell F. Theriot, Environmental Laboratory (EL), WES, was the Wetlands Research Program Manager. Dr. Landin was the Task Area Manager.

Participants in the study, in addition to the authors, included Mr. Matt Davis of the U.S. Army Engineer District, Sacramento. The Sacramento District, in coordination with WES, contracted with the University of California, Davis, for the work described in this report. The authors of the report were Ms. Michelle Stevens and Dr. Eliska Rejmankova, Botany Department, University of California, Davis. Mr. Robert Lazor, EL, was instrumental in facilitating the initial coordination with the District to achieve the contractual effort. The report was technically reviewed by Dr. Landin and Mr. John Tingle, EL.

The report was prepared under the direct supervision of Mr. Hollis H. Allen, Acting Chief, Stewardship Branch, and under the general supervision of Dr. Robert M. Engler, Chief, Natural Resources Division, and Dr. Edwin A. Theriot, Assistant Director, and Dr. John Keeley, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as follows:

Stevens, M., and Rejmankova, E. (1995). "Cache Slough/Yolo Bypass wetlands demonstration area, mitigation assessment," Technical Report WRP-RE-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
degrees Fahrenheit	5/9	degrees Celsius or Kelvins[1]
feet	0.3048	meters
inches	25.4	millimeters
miles	1.609347	kilometers
quarts (U.S. liquid)	0.0009463529	cubic meters

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

1 Introduction

This document provides preliminary monitoring data on the Cache Slough/ Yolo Bypass mitigation area. The objectives of the study are to monitor mitigation success in relation to project goals and objectives in comparison with adjacent reference areas. The overall goal is to describe the long-term spatial pattern of marsh evolution. The sediment accretion pattern and change of bathymetry and vegetation composition over time may allow prediction of long-term restoration trends. Compiling a long-term database of sediment accretion rates, revegetation, and marsh building processes will contribute towards prioritization of potential mitigation/restoration sites and improve predictability in the planning process for successful replication of wetland values and functions.

Quantitative data collected in 1992 and 1993 and some qualitative data from 1994 are included in this report. Research is ongoing. Monitoring protocols are consistent with other demonstration sites funded nationally by the Wetlands Research Program, U.S. Army Engineer Waterways Experiment Station. This study provides background information on site conditions, vegetation species composition, soils, water quality, and hydrology at both the mitigation and reference areas (Appendix A-F).

The Cache Slough site is located west of the Sacramento River in the northern area of the Sacramento-San Joaquin Delta, about 8 miles[1] north of Rio Vista, California (Figure 1). The study area is a triangular-shaped piece of land bordered by Cache and Shag Sloughs to the east and west and a cross levee to the north. The 176-acre area has been reconfigured to form islands and a deepwater habitat with a shallow bordering emergent zone and vegetated levees. Breaching of the two levees has resulted in diurnal tidal influence, the fetch of prevailing winds and waves, as well as the continually shifting mosaic which occurs with a dynamic hydrologic regime. Soils are unconsolidated clay and peat (Figure 2) and are extremely unstable. (Erosion was occurring at a rate of 10 cm soil/week in portions of the site in 1992; it appears to have slowed significantly in 1993 and 1994 because of the implementation of erosion control measures.)

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1 A table of factors for converting non-SI units of measurement to SI units is presented on page x.

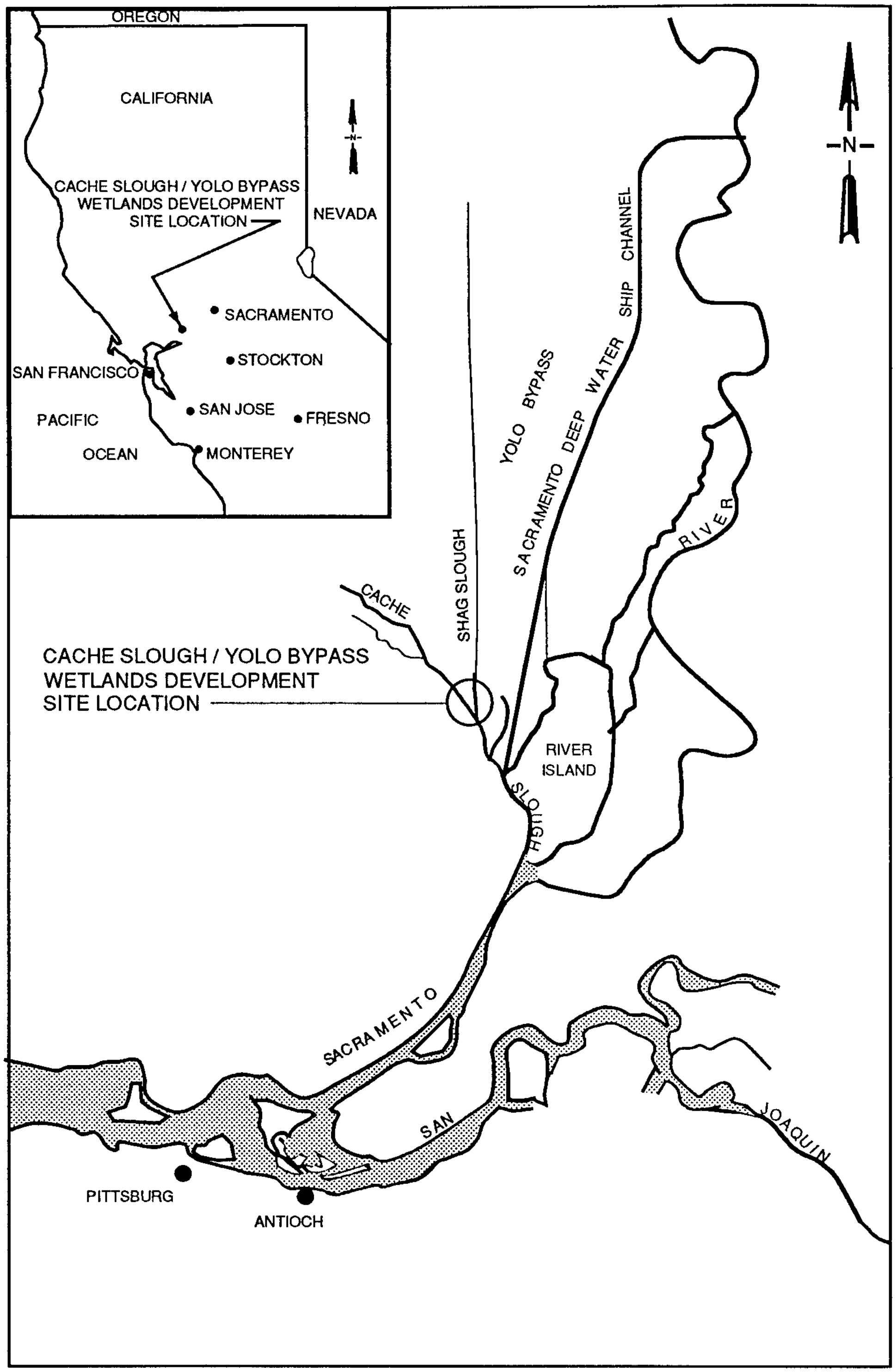


Figure 1. Site map of Cache Slough/Yolo Bypass mitigation area

The mitigation area was designed and constructed by the U.S. Army Corps of Engineers to mitigate impacts to fish and wildlife habitats from the Sacramento River Bank Protection Project (SRBPP) (U.S. Army Corps of Engineers

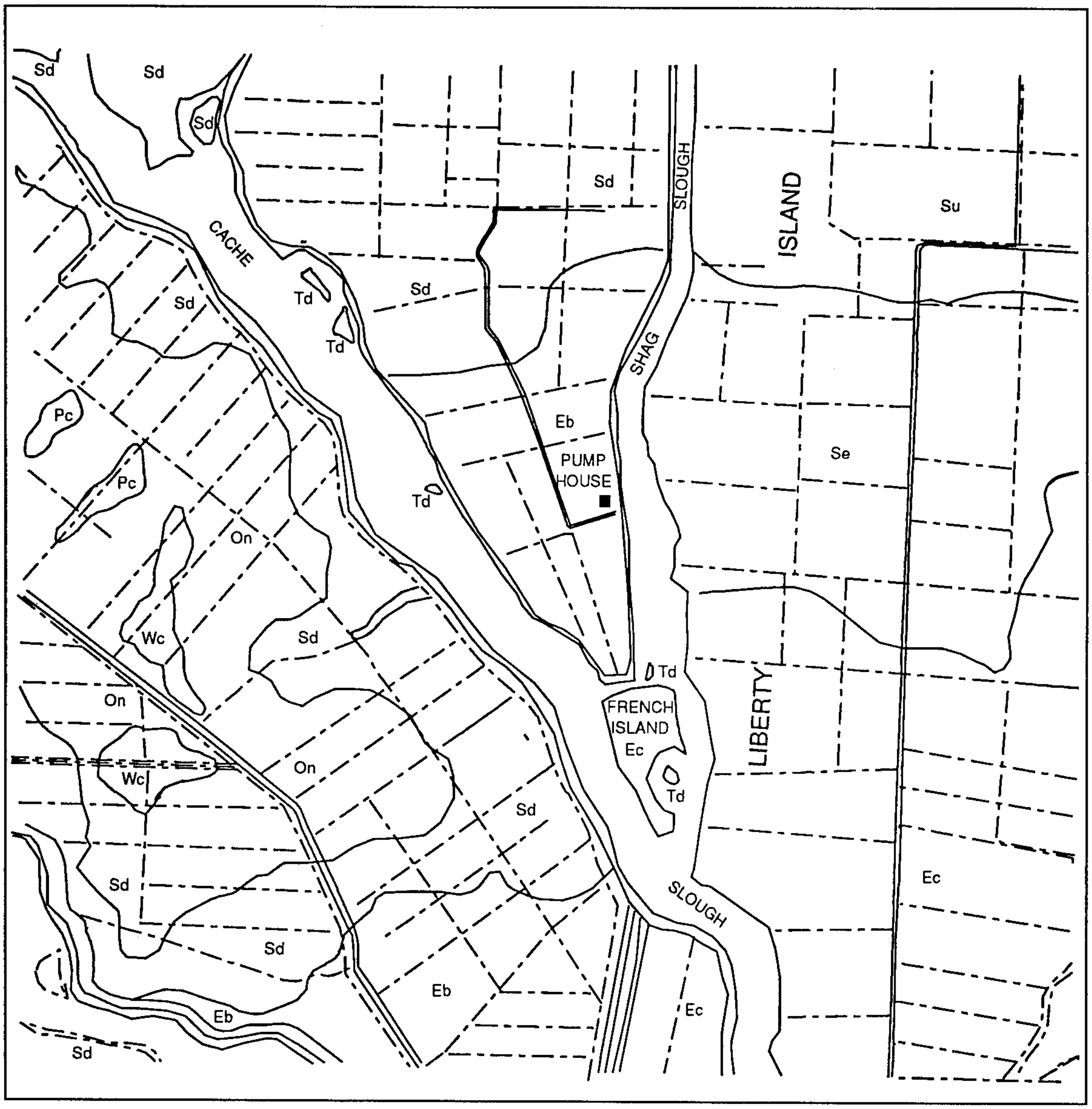


Figure 2. Soils map, Solano County (soils are primarily Eb - Egbert series, consisting of level alluvial soils, primarily gray silty clay loam)

1990, 1991; U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers 1987, 1989). The mitigation area consists of approximately 9,000 linear feet (approximately 38 acres) of bypassed levee and a 138-acre interior basin area of primarily open water habitat with two islands and a surrounding fringe of emergent and submerged vegetation. Hydrologic conditions necessary for actual establishment of wetland habitats were created when levees bordering the area were abandoned and breached in May 1992. Palustrine emergent, scrub-shrub, and forested cover types are developing onsite.

2 Methods

During the field season in 1992, permanent transects were established to record revegetation on the site (Cook 1991, Grieg-Smith 1983). Extensive quantitative sampling was completed in the field seasons of 1992 and 1993. Qualitative observations for 1994 are included; not included is quantitative field sampling collected during the 1994 field season. Eight transects with associated permanent vegetation quadrats were established around the perimeter of the open-water component of the mitigation area; species composition, relative abundance, and frequency were measured. Rebar was used to mark the beginning and end of each transect in order to relocate them each year. Quadrats measuring 18 in. square were placed every 10 ft.

Emergent Vegetation

Emergent vegetation was sampled in five transects around the mitigation site (Figure 3). Transect 1 is located in the north, Transect 2 in the east (north of the breach), Transect 3 in the east (south of the breach), Transect 4 is in the southwest, and Transect 5 is in the northwest. More detailed information is given in Appendix A. In addition to the emergent vegetation transects, two long transects include the entire gradient of the site, giving an indication of total species composition (Figure 4).

Long Transect #1 is located on the southeast corner of the site, running to the northwest corner of the site. The transect proceeds at 52 deg, from the stake to the right side of the cottonwood trees across the site, and over one of the islands. Long Transect #1 was established on September 18, 1992. Quadrats were taken every 10 ft, except when over open water.

Long Transect #2 is located on the northeast corner of the site, and proceeds to the west. Established on September 21, 1992, the transect begins at the gate post and heads toward the fourth transmission tower south of the breach. Both islands were sampled with this transect.

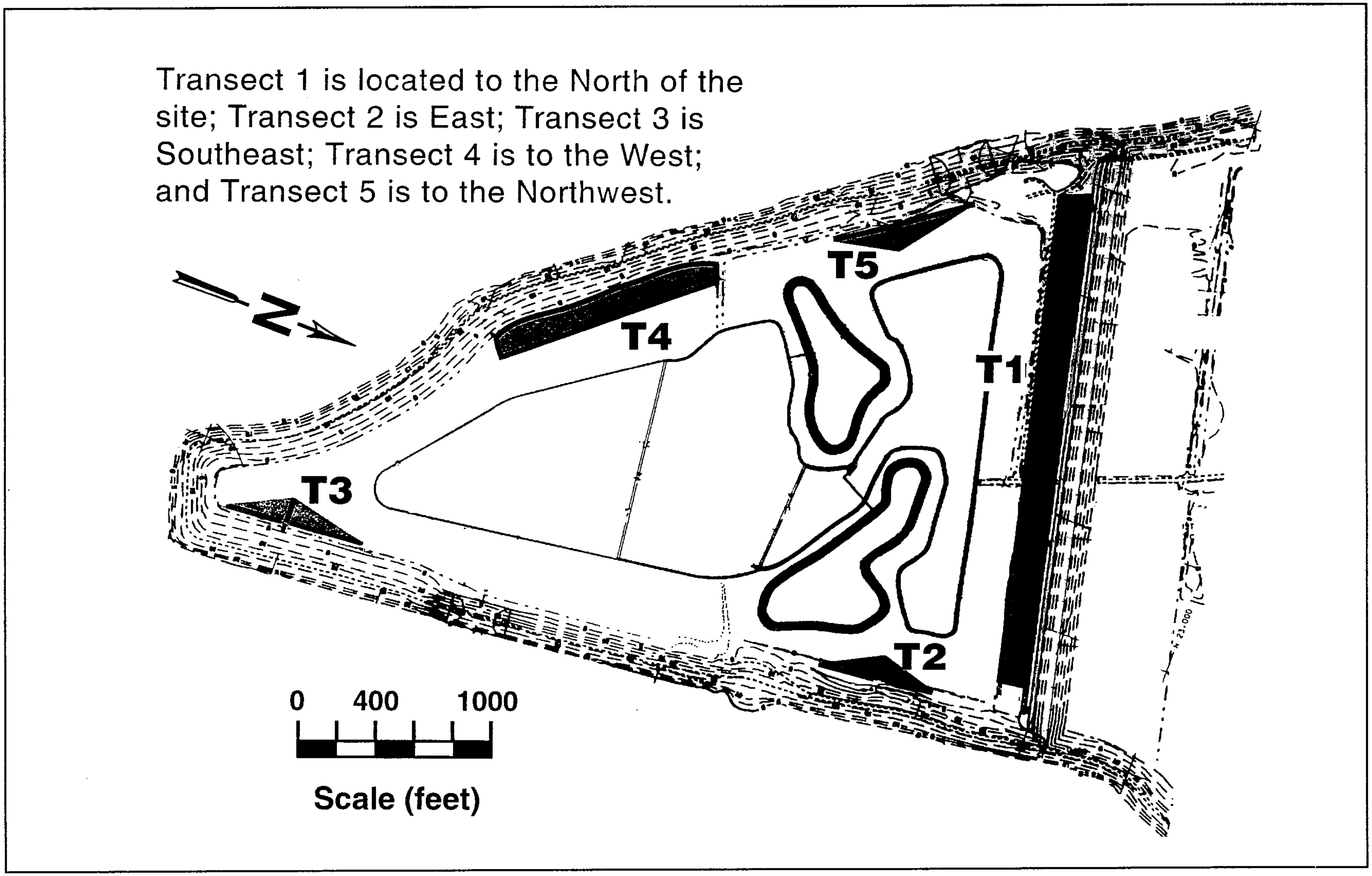


Figure 3. Vegetation transects - emergent vegetation

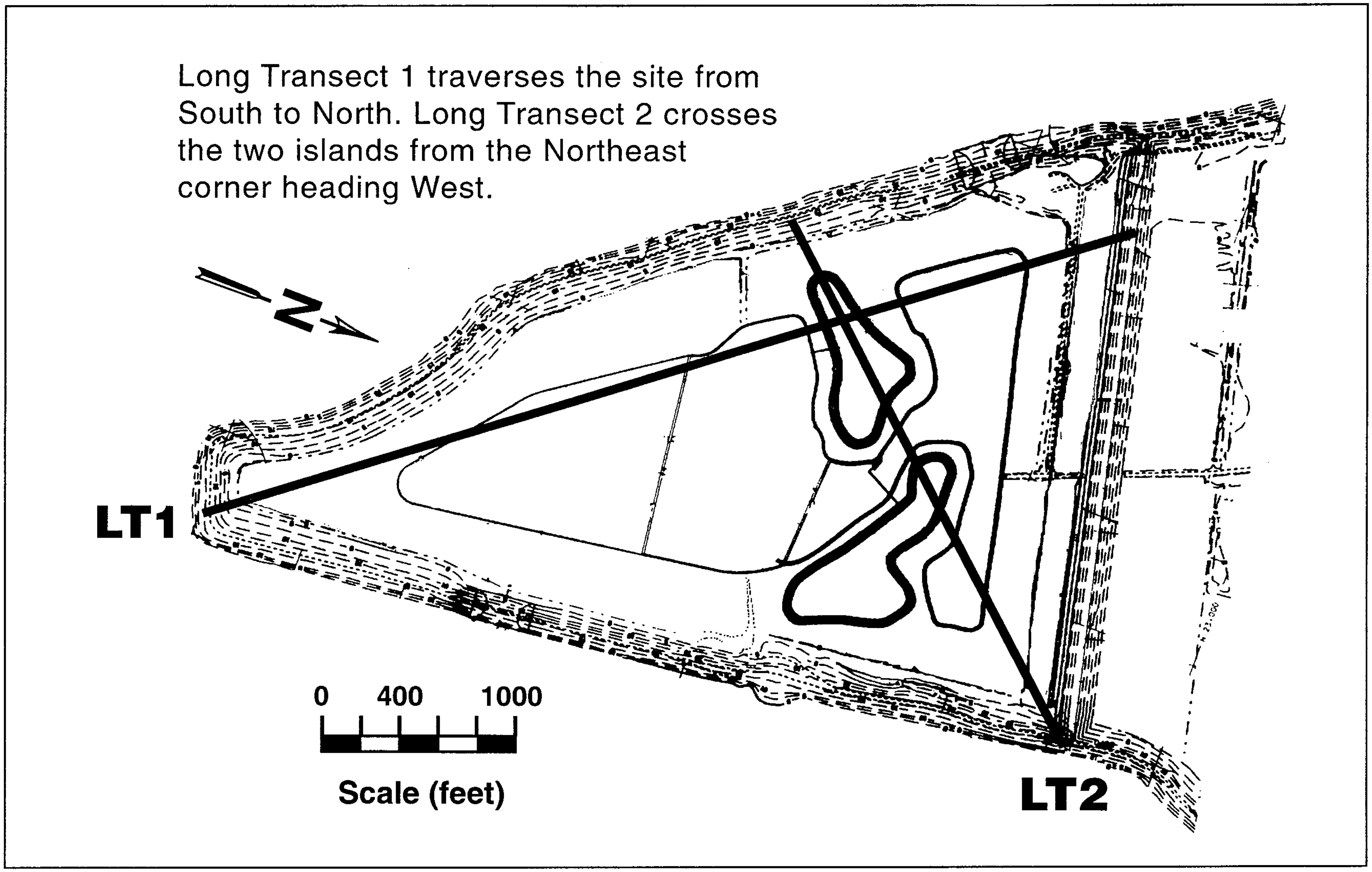


Figure 4. Vegetation transects - gradient analysis

Reference Site Transects

In 1993, two transects were placed in the reference area. This area is located due north of the mitigation site on Cache Slough. It is approximately 1 mile from the mitigation site. Vegetation composition is similar to that proposed for the mitigation site; the area is composed of a vegetated island, open water, and surrounding steep bank with palustrine emergent, scrub-shrub, and forested riparian species characteristic of the Sacramento-San Joaquin Delta. The site was selected as an appropriate local target as it appeared to be a realistic template for the Cache Slough site; it was selected after construction was completed. The major problem with the reference site is that the hydrology is not open to diurnal tidal cycles or annual flooding cycles; it is managed with a constant water level for irrigation purposes.

Transect #7 is established by heading due east across the reference area. This transect was established July 29, 1993. The distance between the transect and the road corner is 71.2 ft. The transect was marked every 25 to 50 ft, with a quadrat every 10 ft.

Transect #8 is established in the reference site heading east at a compass bearing of 60 deg. It is 90 ft north of the road corner. The transect was marked every 25 to 50 ft, with a quadrat every 10 ft.

Woody Vegetation

Woody vegetation was monitored throughout the site. A total census of the population was taken; every individual was sampled. Stem height, number of stems, and number of dead individuals of each species were recorded. Percent survival, number of stems, stem height, and relative abundance in species composition were monitored. Sampling dates were October 14, 1992, October 21, 1992, and September 21, 1993. Woody vegetation was sampled in September and October in 1992 and 1993.

Permanent Photo Stations

Permanent photo stations were established around the site. The first station is located in the southeast corner of the site and was established September 18, 1992. This is also the beginning of Long Transect #1. The second photo station is at the gate at the northeast corner of the site along the second long transect. Other photo stations occur around the site, particularly in rapidly eroding areas.

Aerial Photo Interpretation

Aerial photographs were obtained from the Sacramento District at low tide in July 1993. Vegetation cover types including riparian vegetation, emergent vegetation, open water, upland shrub, and upland herbaceous vegetation have been assessed using these photographs. The scale of the photograph used is 1 in. equals 150 ft. Aerial photographs were field truthed by walking around the site March 10, 1994, and delineating woody vegetation on the photograph. Aerial photography will be exceptionally useful for documenting changes in both vegetation cover and sediment accretion over time.

Soil Samples

In field season 1993, soil samples were collected and analyzed through standard laboratory procedures (DANR Analytical Laboratory 1994). Twenty-four samples collected April 11, 1993, were analyzed for calcium, magnesium, sodium, chlorine, sulfate, total nitrogen, percent organic matter, and soil texture. In a second sampling, 49 samples collected August 16 were analyzed for the above. Samples 5 cm by 5 cm by 5 cm were collected, with three replicates per sample location. See Figure 5 for sampling locations.

Preliminary observations indicate that sediment is eroding from the site. Erosion control measures were implemented in early spring 1993. Hay bales were installed with willow cuttings holding them in place on the east bank. Most bales and willows survived the growing season. In late fall, beaver activity topped several of the willows; it is unclear how many of the plants were killed. Emergent vegetation was also planted along the shore. Additional erosion control measures were implemented in the spring of 1994 with willow cuttings and hay bales installed in areas which were washed out.

In addition, emergent vegetation, i.e. hardstem bulrush (*Scirpus acutus*), was installed in sausage-shaped geotextile rolls made from coconut husk fiber and surrounded by a coconut-mesh rope material called "COIR." These rolls were placed end-to-end in front of the hay bales to form a mini-breakwater. Photographic documentation was performed to monitor the development of these rolls and their effects on erosion control.

Sediment Budget

Sediment budget data were collected from 0715 hr to 2245 hr on August 11, 1993. The sampling period included low high tide, high low tide, and high high tide; low low tide was not included. The period chosen in August is representative of an average tidal cycle during an average water condition during the year. Heavy runoff or high flows in Shag or Cache Sloughs were

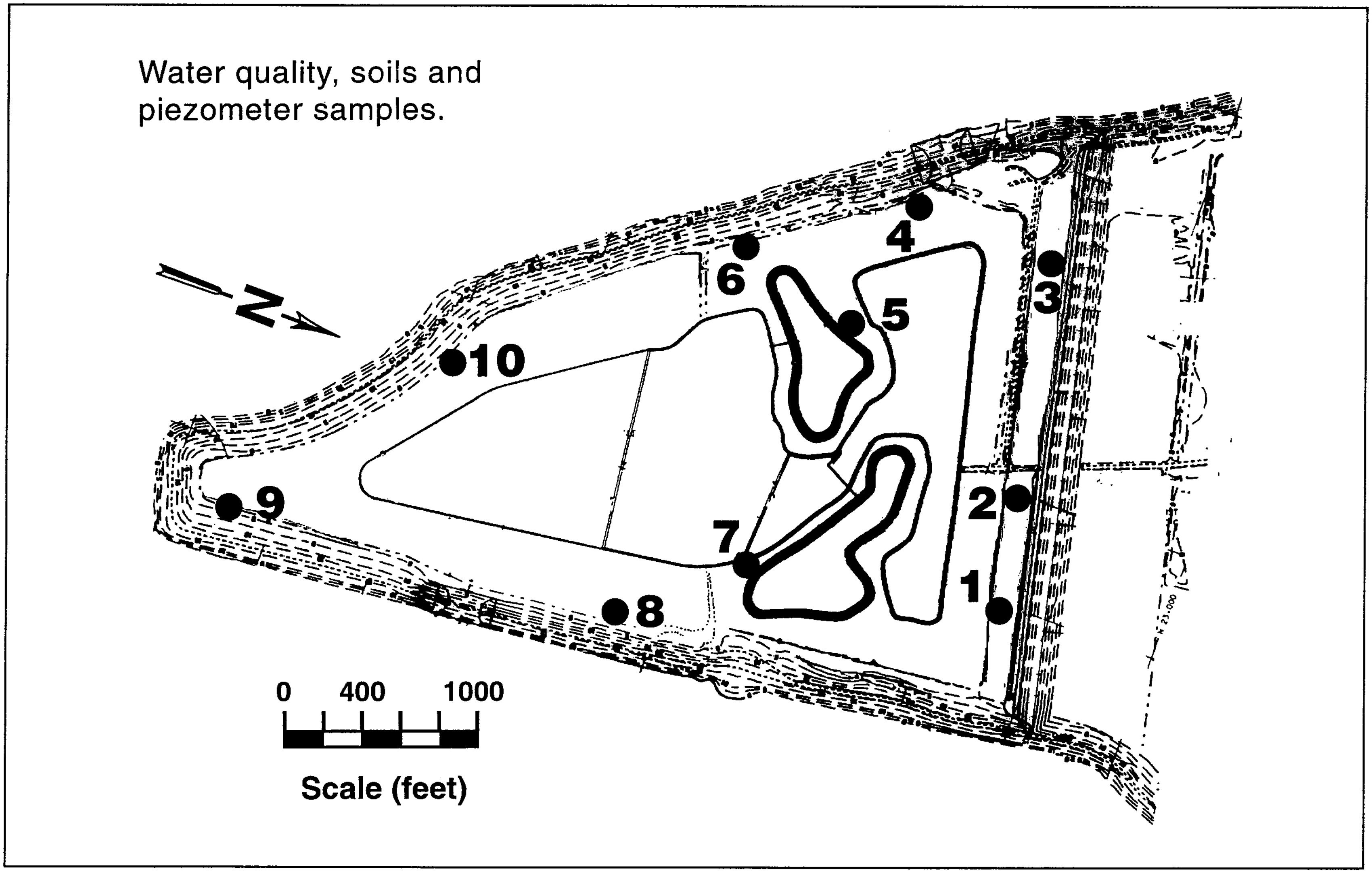


Figure 5. Piezometer locations

not present at this time. Ambient low flow background condition could be measured.

Two boats were used for sampling; one boat was located in the east breach, one boat in the west breach. Samples were taken every 15 min until 1200 (noon), then every 10 min until 1700, then every 15 min until 2245. Three measurements were taken at each sample interval. First, staff gauge readings (measured in tenths of feet) were recorded from a staff held at the side of the boats. Second, an orange was tossed out and recorded as it passed a 10-ft section of the boat. It was timed and direction was noted to derive surface flow measurements. (Oranges were numbered, and it was noted from which side, east or west, they originated.) Approximately 200 oranges were thrown, 100 from each side. Lastly, a 1-qt composite water sample was taken.

In the laboratory, the 1-qt sample was mixed thoroughly, and sediment samples were obtained from a 100-ml subsample. Standard laboratory procedures were utilized to determine suspended sediment in the samples (Janik and Byron 1987).

A sediment budget was developed to qualify sediment input and output on an average tidal cycle. It was established that there is a net sediment flux into the site, and one side is importing sediment while the other is exporting sediment. Based upon these findings, the marsh may develop more on one side than the other. The accretion pattern and change of bathymetry will be monitored to determine the spatial pattern of evolution in the marsh and to conduct a trend analysis of long-term accretion rates (Rejmanek et al. 1988).

Piezometers

Ten piezometers were installed during the spring of 1993 around the mitigation site, and two were installed in the reference area (Figure 5). Representative measurements of surface and interstitial groundwater were taken in both reference and mitigation sites.

Water Samples

One-liter composite water samples were taken throughout the year (Horner 1988). Samples were taken in the water where piezometers are located. Standard laboratory procedures were used to analyze nutrients, including ammonium, nitrogen, and total phosphorus (Janik and Byron 1987).

3 Results and Discussion

Aerial Photograph Interpretation

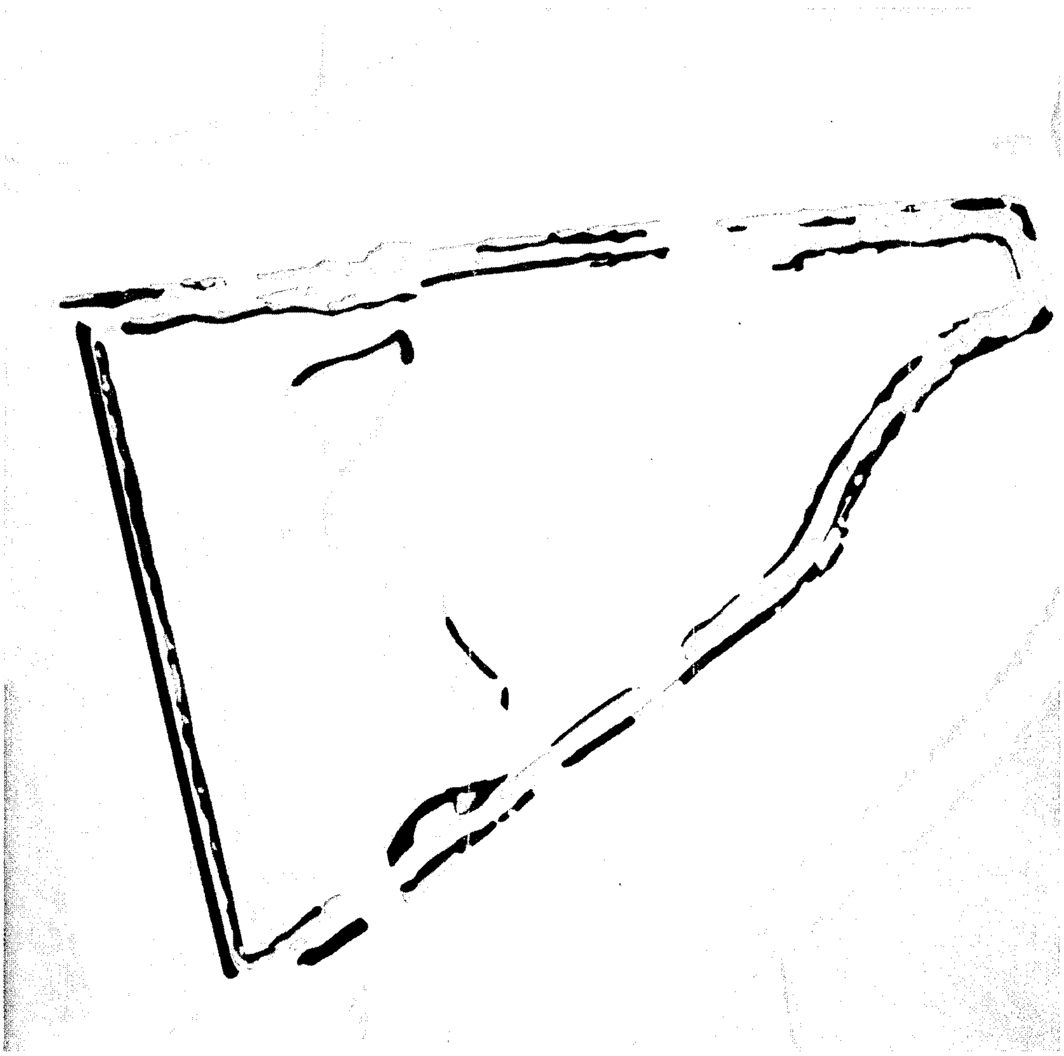
According to the U.S. Army Corps of Engineers (1990) report on the Cache Slough/Yolo Bypass mitigation area, acreage for the site is as follows:

Abandoned Levees Land Area	38.1 acres
Interior Basin (0.0 ft mean sea level contour)	137.8 acres
Total Project Land Area (excluding cross levees)	175.9 acres

The cover types and acreage listed in Table 1 were determined from aerial photographs contracted by the Corps at low tide in July 1993 (Figure 6 and Appendix F). The site was ground truthed, as the riparian areas often have very small saplings (such as the 6-in. oaks) which would not be visible in an

Table 1
Cover Types on the Site (1993)

Cover Type	Acreage	Percent Cover
Open water	125.67	72
Riparian cover type	13.45	8
Emergent wetland vegetation	9.54	5
Upland shrub (blackberry)	6.01	3
Upland - herbaceous	13.10	7
Upland - Island 1 (east)	3.77	3
Upland - Island 2 (west)	2.92	2
Upland - road, parking	0.95	
Riprap (breaches)	0.48	
Cross levee (Excluding emergent vegetation, road, north side of road)	5.55	
Total	181.44 (with cross levee)	



Legend

Color	Cover Type	Acreage
Green	Riparian (Woody Vegetation)	13.45
Red	Emergent Wetland Vegetation	9.54
Purple	Upland Shrub	6.01
Yellow	Disturbed Area (Roads)[1]	1.43
Gray	Open Water - Interior Site	125.67
Gray	Upland - Herbaceous[2]	25.34
Total		181.44

[1] Upland - road, parking + Riprap.
[2] Upland - herbaceous + Island 1 + Island 2 + Cross levee.

Figure 6. Cover types, 1993 aerial photograph

aerial photograph. During ground truthing, vegetation cover types were drawn on an enlarged aerial photograph (1 in.:150 ft); acreage was then derived from this information.

The riparian cover type includes 13.45 acres on the site. All planted areas were included in the acreage assessment. Both the riparian areas and the upland shrub, which is composed primarily of blackberry bushes, provide desirable wildlife habitat. This cover type comprises 11 percent of the site. Levees surrounding the study site are regularly burned in order to remove vegetation for dike maintenance. Existing vegetated levees provide an island of habitat. In particular, upland game birds (particularly pheasant), passerine birds, and small mammals were observed in this habitat type. These habitat islands may be very important for migratory species, particularly in light of the fragmentation and elimination of the majority of riparian corridors in California.

Open water is the major cover type on the site, comprising 125.67 acres, or 71 percent of the site. Emergent wetland vegetation provides 9.54 acres of habitat value, or 5 percent, of the site.

Upland herbaceous vegetation (including the cross levee) includes 25.34 acres and is the dominant cover type, comprising 11 percent of the site. Disturbed areas include 1.43 acres of the site.

Only 28 percent of the site is vegetated; the rest is primarily composed of open-water cover type. Sixteen percent of the site is vegetated with native species (riparian, emergent, and upland shrub cover types), and 12 percent of the site is composed of herbaceous exotic species (such as star thistle, wild oat, ox tongue, bull thistle, ryegrass, peppergrass, harding grass, and prickly lettuce) or disturbed unvegetated areas.

Species composition is discussed under the vegetation section which follows.

Vegetation

The U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps depict the area around the levees as palustrine emergent (PEMN) (Figure 7). Naturally formed islands within the sloughs have been mapped as palustrine scrub-shrub (PSSR), with French Island mapped as both palustrine scrub-shrub and emergent (PSS/EMR). The area interior of the levees was agricultural land, and not mapped on the NWI maps. The reference area is mapped as palustrine emergent (PEMHx).

Native vegetation along the levees is representative of the delta and includes the following: willows (*Salix goodingii, S. lasiolepis*), elderberry (*Sambucus* sp.), black walnut (*Juglans hindsii*), valley oak (*Quercus lobata*), interior live oak (*Quercus wizlizenii*), white alder (*Alnus rhombifolia*),

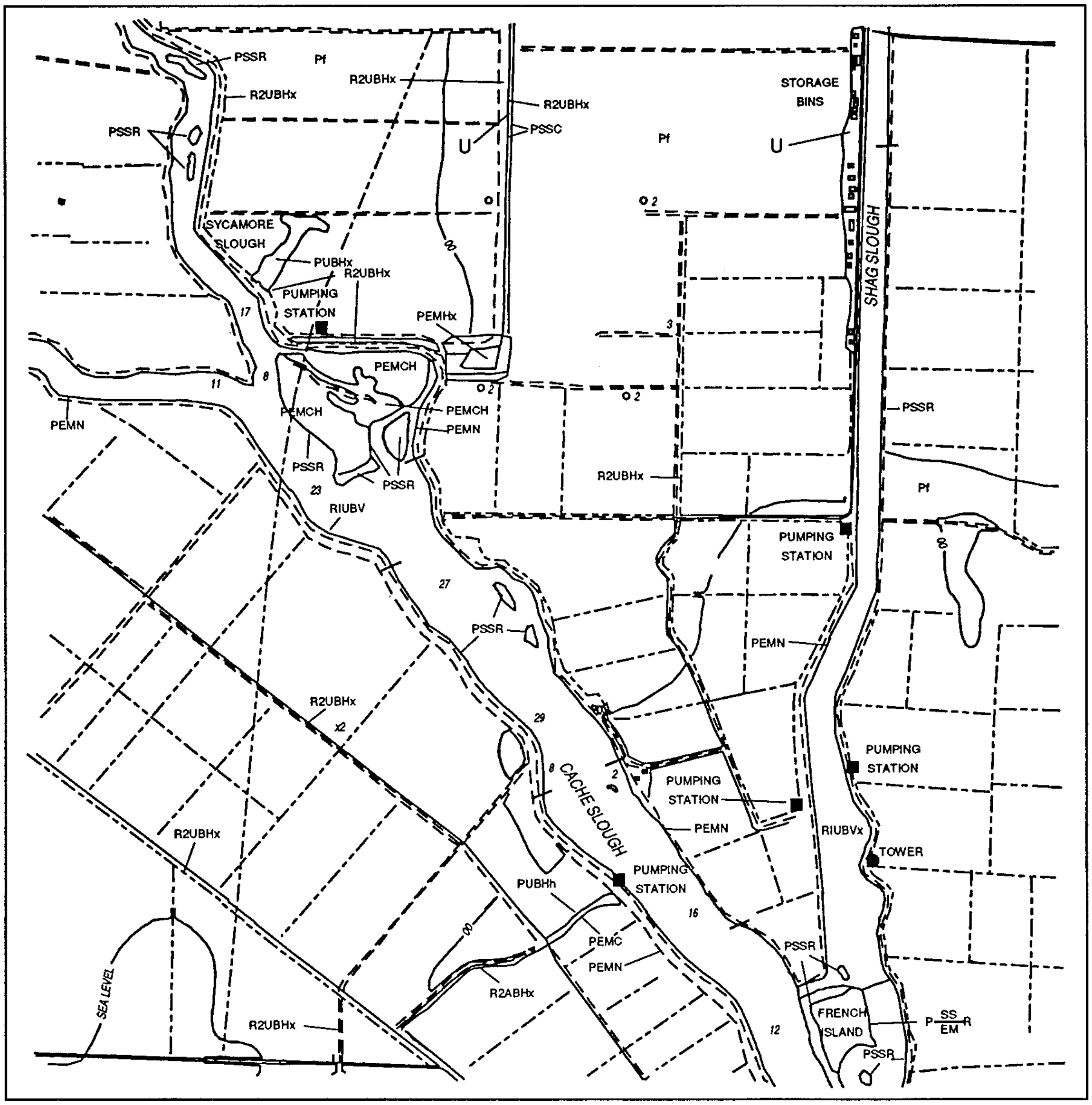


Figure 7. National Wetland Inventory map (The majority of vegetation onsite is not classified as wetland. At the time of mapping, the site was converted agricultural lands. Palustrine emergent and palustrine scrub-shrub are mapped outside the dikes.)

cottonwood (*Populus fremontii*), hard-stem bulrush (*Scirpus acutus*), cattail (*Typha* spp.), and horse tail (*Equisetum* sp.). Prevalent non-native species include blackberry (*Rubus* spp.), artichoke (*Cynara scolmus*), sweet fennel (*Foeniculum vulgare*), star thistle (*centaurea solstitialis*), and California oat (*Avena fatua*).

The following riparian communities have been described by the California Department of Fish and Game Natural Diversity Data Base for Natural Communities of California which could potentially be found historically in the area of the mitigation site (Holland 1986): Riparian Forests - Great Valley Riparian Forests; Riparian Forests - Great Valley Mixed Riparian Forest; Great Valley

Willow Scrub; and Coastal and Valley Freshwater Marsh (Appendix E). Descriptions of these communities provide a good example of the reference or presettlement condition occurring in the study area prior to agricultural development and flood control.

Vegetation Data - 1993

Dominant vegetation throughout the site is represented by species composition included in Table 2. Eighty-seven percent of the site is dominated by non-native species (as measured by relative abundance). Yellow starthistle (*Centaurea solstitialis*), oxtongue (*Picris echiodides*), ryegrass (*Lolium* sp.), phalaris (*Phalaris aquatica*), wild oats (*Avena fatua*) and prickly lettuce (*Lactuca serriola*) represent 82 percent of the relative abundance (69 percent of relative frequency) of species on the site. All of these species are introduced ruderal species with aggressive and weedy characteristics. Hardstem bulrush (*Scirpus acutus*), golden nutsedge (*Cyperus eragrostis*), spike-rush (*Eleocharis macrostachya*) and cattail (*Typha latifolia*) make up 11 percent of relative abundance (9 percent relative frequency), and are native wetland species.

In Table 3, transect data are summarized for emergent vegetation in the mitigation site (Transects 1-6). Ninety-six percent of the emergent vegetation is native. Thirty-nine species of emergent vegetation were identified. Tule (*Scirpus acutus*), golden nutsedge (*Cyperus eragrostis*), and cattail (*Typha latifolia, Typha domingensis*) dominate the emergent vegetation (78 percent relative abundance, 69 percent relative frequency). *Juncus phaeocephalus, Scirpus mucronatus, Lycopus americanus, Lactuca serriola,* and *Sagittaria latifolia* are common in emergent vegetation (13 percent relative abundance, 15 percent relative frequency).

Table 4 summarizes data for the reference area. Seventy-four percent of the site is dominated by native vegetation (as opposed to 12 percent for the mitigation site). Thirty-four species of emergent vegetation were identified. Dominant species include *Scirpus acutus, Rubus* spp., *Ludwigia peploides, Salix scouleriana, Polygonum lapathifolium, Salix lasiandra, Salix* spp., and *Centaurea solstitialis.* These species comprise 83 percent of the relative abundance and 69 percent of the relative frequency. Actually, the transect represents a gradient comparable to Long Transects 1 and 2. The starthistle (*C. solstitialis*) is comparable to the dominant vegetation on the mitigation site, with other dominant species such as ox-tongue (*Picris echioides*), ryegrass (*Lolium* sp.), phalaris (*Phalaris aquatica*), wild oats (*Avena fatua*), and prickly lettuce (*Lactuca serriola*) also occurring in this area. A wooded border occurs around the open-water habitat, with *L. peploides* occurring as a creeping emergent around both the upland shore and interior island. The island is dominated by tule (*Scirpus acutus* primarily) with dense wooded areas of willow and blackberry also occurring.

Table 2
Transect Total - Transects LT-1 and LT-2

Species	Rel. AB[1]	Rel. F[2]	Origin
Centaurea solstitialis	20	16	Non-native
Picris echiodides	19	15	Non-native
Lolium species	16	12	Non-native
Phalaris aquatica	13	8.5	Non-native
Avena fatua	8	8	Non-native
Lactuca serriola	6	8	Non-native
Scirpus acutus	5	3	Native
Cyperus eragrostis	4	4	Native
Ammi visnaga	2	3	Non-native
Brassica nigra	1	2	Non-native
Eleocharis macrostachya	1	1	Native
Typha latifolia	1	1	Native
Calystegia species	0.5	2	Non-native
Echinochloa crusgalli	0.5	1	Non-native
Baccharis viminea	0.5	0.5	Native
Convolvulus species	0.5	0.5	Non-native
Malva species	0.5	0.5	Non-native
Ammania coccinea	0.5	0.5	Native
Circium vulgaris	0.5	0.5	Non-native
Antennaria species	0	1	Non-native
Polygonum species	0	1	Non-native
Raphanus species	0	1	Non-native
Bidens laevis	0	1	Native
Atriplex species	0	0.5	Native
Cyperus laevigatus	0	0.5	Native
Melilotus officinalis	0	0.5	Non-native
Plantago species	0	0.5	Non-native
Polygonum laphathifolium	0	0.5	Native
Rumex pulcher	0	0.5	Non-native
Sambucus mexicana	0	0.5	Native
Taraxacum officinale	0	0.5	Non-native
Species Total	32		

1 Relative abundance.
2 Relative frequency.

Table 3
Transect Total - Transects 1-6

Species	Rel. AB[1]	Rel. F[2]	Origin
Scirpus acutus	37	22	Native
Cyperus eragrostis	19	26	Native
Typha latifolia	12	12	Native
Typha domingensis	10	9	Native
Juncus phaeocephalus	4	5	Native
Typha species	4	4	Native
Scirpus mucronatus	2	2	Native
Lycopus americanus	1	2	Native
Lactuca serriola	1	2	Native
Sagittaria latifolia	1	0.7	Native
Salix laevigata	0.7	0.9	Native
Salix species	0.7	0.5	Native
Typha angustifolia	0.7	0.5	Native
Alisma plantago-aquatica	0.7	0.4	Native
Verbena hastata	0.5	1	Native
Bidens laevis	0.5	0.4	Native
Cyperus laevigatus	0.4	0.9	Native
Phragmites australis	0.4	0.7	Native
Mentha arvensis	0.4	0.4	Non-native
Scirpus californicus	0.4	0.5	Native
Centaurea solstitialis	0.4	0.4	Non-native
Purple unknown #2	0.4	0.4	Unknown
Polygonum persicaria	0.2	0.9	Non-native
Lolium species	0.2	0.7	Non-native
Setaria species	0.2	0.7	Non-native
Lepidium latifolium	0.2	0.4	Non-native
Polygonum lapathifolium	0.2	0.4	Native
Ammania coccinea	0.2	0.2	Native
Eleocharis macrostachya	0.2	0.2	Native
Phalaris aquatica	0.2	0.2	Non-native
Unknown grass	0.2	0.2	Unknown

(Continued)

[1] Relative abundance.
[2] Relative frequency.

Table 3 (Concluded)			
Species	**Rel. AB[1]**	**Rel. F[2]**	**Origin**
Polygonum species	0	0.9	Non-native
Rumex pulcher	0	0.7	Non-native
Convulvus species	0	0.4	Non-native
Plantago species	0	0.4	Non-native
Ludwigia peploides	0	0.2	Native
Polygonum	0	0.1	Native
Hydropiperoides	0	0.2	Native
Solanum americanum	0	0.2	Non-native
Taraxacunm officinale	0	0.2	Non-native
Species Total	40		

Reference Area Transect #7 is dominated by *Scirpus acutus, Rubus* spp., *Salix scouleriana,* and *Ludwigia peploides.* Twenty species occur along this transect. Transect #8 is dominated by *S. acutus, Rubus* spp., *L. peploides, Salix lasiandra, Salix* spp., *Polygonum lapathifolium,* and *Centaurea solstitialis.* Other common species include *Phragmites australis, Salix scouleriana, Salix lasiolepis, Cyperus eragrostis, Epilobium glaberrimum, Holcus* sp., *Lycopus americanus, Polygonum persicaria,* and *Typha latifolia.*

Emergent Vegetation Data

Emergent vegetation was sampled in 5 transects positioned in homogeneous units within the welted perimeter of the mitigation site (Figures 3 and 4). Codominants for all transects include *Scirpus acutus, Cyperus eragrostis,* and *Typha* spp. The west side of the site, leeward of prevailing winds, has the highest species diversity on site (26 species) and is 70 percent vegetated. The south side of the site also has relatively high species diversity (19 species), but is only 50 percent vegetated because of higher erosion rates. In 1992, the east side of the site (where prevailing wave and wind action cause high erosion rates and substrate instability) had only 11 species and was primarily unvegetated. In 1993, erosion control measures resulted in reduced erosion rates and an increase in species diversity and vegetation. By July 1994, erosion control measures have resulted in continuous vegetation along the east bank, and erosion has been reduced dramatically. The north side of the site has 14 species and is 63 percent vegetated.

In 1993, Transect 1 was dominated by *Scirpus acutus, Cyperus eragrostis,* and *Juncus phaeocephalus.* Ninety percent of the area sampled was vegetated. Co-dominants included *Bidens laevis* and *Lepidium latifolium.* Only five species were identified; this is due to sampling error rather than reduction in

Table 4
Transect Total - Reference Area - Transects 7 and 8

Species	Rel. AB[1]	Rel. F[2]	Origin
Scirpus acutus	31	24	Native
Rubus species	16	15	Non-native
Ludwigia peploides	9	7	Native
Salix scouleriana	6	4	Native
Polygonum lapathifolium	6	8	Native
Salix lasiandra	5	4	Native
Salix species	5	4	Native
Centaurea solstitialis	5	3	Non-native
Typha species	3	3	Native
Phragmites australis	3	3	Native
Epilobium glabberimum	1	3	Native
Polygonum species	1	2	Non-native
Cyperus eragrostis	1	3	Native
Glaium aparine	1	2	Non-native
Juncus species	1	1	Native
Salix lasiolepis	1	1	Native
Typha domingensis	1	1	Native
Verbena hastata	0.5	2	Native
Holcus species	0.5	1	Non-native
Lycopus americanus	0.5	1	Native
Rosa species	0.5	0.5	Unknown
Ammannia coccinea	0.5	0.5	Native
Juncus phaeocephalus	0.5	0.5	Native
Polygonum persicaria	0.5	0.5	Non-native
Typha latifolia	0.5	0.5	Native
Scirpus olneyi	0	1	Native
Ammi visnaga	0	0.5	Non-native
Avena fatua	0	0.5	Non-native
Bidens laevis	0	0.5	Native
Carex species	0	0.5	Native
Lolium species	0	0.5	Non-native
Stachys species	0	0.5	Unknown
Species Total	40		

[1] Relative abundance.
[2] Relative frequency.

species diversity from 1992. The area sampled was non-representative, with transects truncated prematurely in an effort to achieve a homogeneous sampling. In fact, there is a remarkable difference in the northern portion of the site from 1992 to 1994. The entire area is solidly vegetated, with species diversity representative of the native emergent wetland flora of California. Sampling methodology is being redesigned in 1994 to better represent diversity occurring onsite.

In 1992, Transect 1 was dominated by *Scirpus acutus, Cyperus eragrostis,* and *Typha* spp. *Aster chilensis, Leptochloa fasicularis, eleocharis macrostachya,* and *Juncus phaeocephalus* also occur with greater than 1 percent abundance in this area. Fourteen species were identified in this location, with 63 percent of the site covered by vegetation.

In 1993, Transect 2 was dominated by *Typha latifolia, Scirpus acutus, Typha domingensis, Sagittaria latifolia,* and *Scirpus mucronatus. Cyperus eragrostis, Lactuca serriola, Lycopus americanus, Phalaris aquatica, Phragmites australis,* and *Solanum americanum* also occur in this area. Fourteen species were identified. Because of erosion from waves, this area remained fairly constant in size and species composition between 1992 and 1993. Vegetation tends to become established in the spring and early summer, and then decreases in aerial extent when summer winds increase in August. In 1994, erosion control and revegetation measures appear to have resulted in a significant increase in species cover, at least when observed in July.

In 1992, Transect 2 was dominated by *Scirpus acutus* and *Typha* species. *Sagittaria latifolia, Epilobium glaberrimum, Cyperus eragrostis, Juncus phaeocephalus, Polygonum persicaria, Phragmites australis,* and *Bidens laevis* occur with greater than 1 percent abundance. *Phragmites* is only 1 percent of the relative abundance of plant composition. Eleven species were identified, with 94 percent of the area vegetated. This area is subjected to prevailing winds and wave action, and was eroding fairly extensively; this limited revegetation success.

In 1993, Transect 3 had increased in area. Ninety-one percent of the site was covered with vegetation. Dominant plant species remained *Cyperus eragrostis, Scirpus acutus,* and *Typha* spp. Eleven species were identified in this area; *Verbena hastata, Ammania coccinea, Plantago* species, *Polygonum hydropiperoides, Rumex pulcher,* and *Taraxacum officianle* were subdominants. *Phragmites* had not increased appreciably in abundance.

In 1992, Transect 3 was dominated by *Cyperus eragrostis, Scirpus acutus,* and *Typha* species. Other species occurring in this area included *Polygonum persicaria, Echinochloa crusgalli, Bidens laevis, Phragmites australis, Samolus floribundus, Polygonum lapathifolium, Cyperus laevigatus, Salix lasiolepis,* and *Polygonum argyrocoleon. Phragmites* reached only 1 percent of the relative abundance in this transect as well. Nineteen species were identified from this location, with 50 percent of the area vegetated. This area was relatively protected from prevailing winds and is steadily revegetating.

In 1993, Transect 4 was dominated by *Cyperus eragrostis, Typha* spp., and *Scirpus acutus*. Fourteen species occurred on this site. Seventy-nine percent of the site was vegetated. Fewer weedy exotic species were occurring in the emergent area than last year, and the vegetated area had stabilized. Less erosion was occurring. This area is affected by prevailing winter winds, and revegetation is considerably slower than in other areas of the site.

In 1992, Transect 4 was dominated by *Typha* spp., *Cyperus eragrostis, Samolus floribundus,* and *Echinochloa crusgalli.* Other emergent species included *Lolium* sp., *Polygonum persicaria, Picris echioides, Aster chilensis, Melilotus officinalis,* and *Rumex pulcher.* Sixteen species were identified from this area, with 56 percent of the area vegetated. More weedy exotic species, such as *Echinochloa, Picris,* and *Melilotus*, occurred in this emergent area than in other areas sampled.

In 1993, Transect 5 had expanded appreciably in aerial extent, and transects were re-established to include the larger area. This area of the site had the highest species diversity, the least invasive exotic species, and seemed to be the most resilient to erosion. Ninety-two percent of the site was vegetated. Dominants included *Scirpus acutus, Cyperus eragrostis, Juncus phaeocephalus,* and *Typha* spp. Twenty-seven species were identified in this area. Ninety-one percent of the species were native (based on relative abundance).

In 1992, Transect 5 was dominated by *Cyperus eragrostis, Typha* species, and *Scirpus acutus*. Other species included *Polygonum persicaria*, an unidentified purple flowered forb, *Phragmites australis* (3 percent cover), *Melilotus officinalis, Juncus phaeocephalus, Echinochloa crusgalli, Cyperus laevigatus, Lycopus americanus, Salix lasiolepis, Juncus* sp., *Samolus floribundus, Ammannia coccinea, Mentha arvensis, Ludwigia peploides, Centaurea solstitialis,* and *Hydrocotyle* sp. Twenty-six species were identified from this area, and 70 percent of the area was vegetated. This area had the most diversity, and revegetation was actively progressing.

Transect 6 was sampled only in 1993 and was located adjacent to and north of Transect 3. It was dominated by *Scirpus acutus, Cyperus eragrostis, Typha latifolia, Alisma plantago-aquatica,* and *Scirpus mucronatus.* Eighty-two percent of the site was vegetated. Eleven species occurred in this area. This area appeared to be resistant to erosion and was relatively stable.

The long transects give a good representation of species dominance throughout the mitigation site. Relative species composition and abundance did not change between the 1992 and 1993 samplings. Non-native exotic species dominated the site measurably. These included *Phalaris aquatica, Avena fatua, Centaurea solstitialis, Picris echioides*, and *Lolium* sp. Dominant native species occurring in the wetted perimeter included *Scirpus acutus, Cyperus eragrostis, Ammi visnaga* (non-native), *Eleocharis macrostachya, Typha* spp., *Calystegia* sp., and *Echinochloa crusgalli.*

Portions of the site are so densely vegetated with star thistle (*Centaurea solstitialis*) that establishment of woody vegetation is precluded. From qualitative observations in 1994, star thistle is being outcompeted by ox tongue (*Picris echioides*). Prickly lettuce (*Lactuca serriola*) appears to be less abundant than in previous years. Reed grass (*Phragmites australis*) was of some concern as an invasive and often weedy species occurring on the site; now that emergent vegetation has become established, it appears reed grass is unable to outcompete co-dominant native flora.

Ninety-two to ninety-five percent of the areas sampled were vegetated. There is an open water component of these transects that is not included in this estimate. Twenty-seven species were identified from these two gradients. Eighty-seven percent of the species are non-native (based on relative abundance).

Multivariate Analysis

Multidimensional techniques have been developed so that clustering tendencies of plant species can be shown geometrically (Ludwig and Reynolds 1988; Greig-Smith 1983). These ordinations can serve to identify trends in vegetation variation, which may lead to explanations in terms of environmental gradients. Overall, ordination techniques assist the ecologist in the evaluation of plant communities and environmental gradients in an objective and quantifiable manner. This may help eliminate subjective bias in the sampling procedure. Ordinations reduce the sampling data to one or two axes that illustrate stands as points in space. This distance between stands on a graph represents their degree of similarity, and the graph axes may correspond to gradients of environmental factors.

Canonical correspondence analysis (CANOCO) is a procedure developed for simultaneously analyzing plant species and environmental data (Ter Braak 1986, 1987; Kenkel and Orloci 1986). This multivariate statistical procedure maximizes the correlation between the plant species subset and the environmental factors (in this case soils) subset. Intuitively, this procedure seems ideal for ecological interpretation. If the axes lead to a good separation of groups of plant species, the environmental data can provide a possible mechanism for explanation. For example, plant species growing in very wet substrates may be separated from those growing in very dry substrates in the geometric clustering illustrated in the ordination. An explanation of environmental data may help explain that certain nutrients or soils characteristics also occur in either wet or dry environments.

Ten transects were evaluated using CANOCO. Spatial gradients in vegetation data were detected from the data (Figure 8). The first axis was defined by the two gradient transects (Transects 9 and 10 on the positive side of the x-axis); species dominating these transects were upland ruderal non-native species (Figure 9). The second axis was separated by transects in the reference

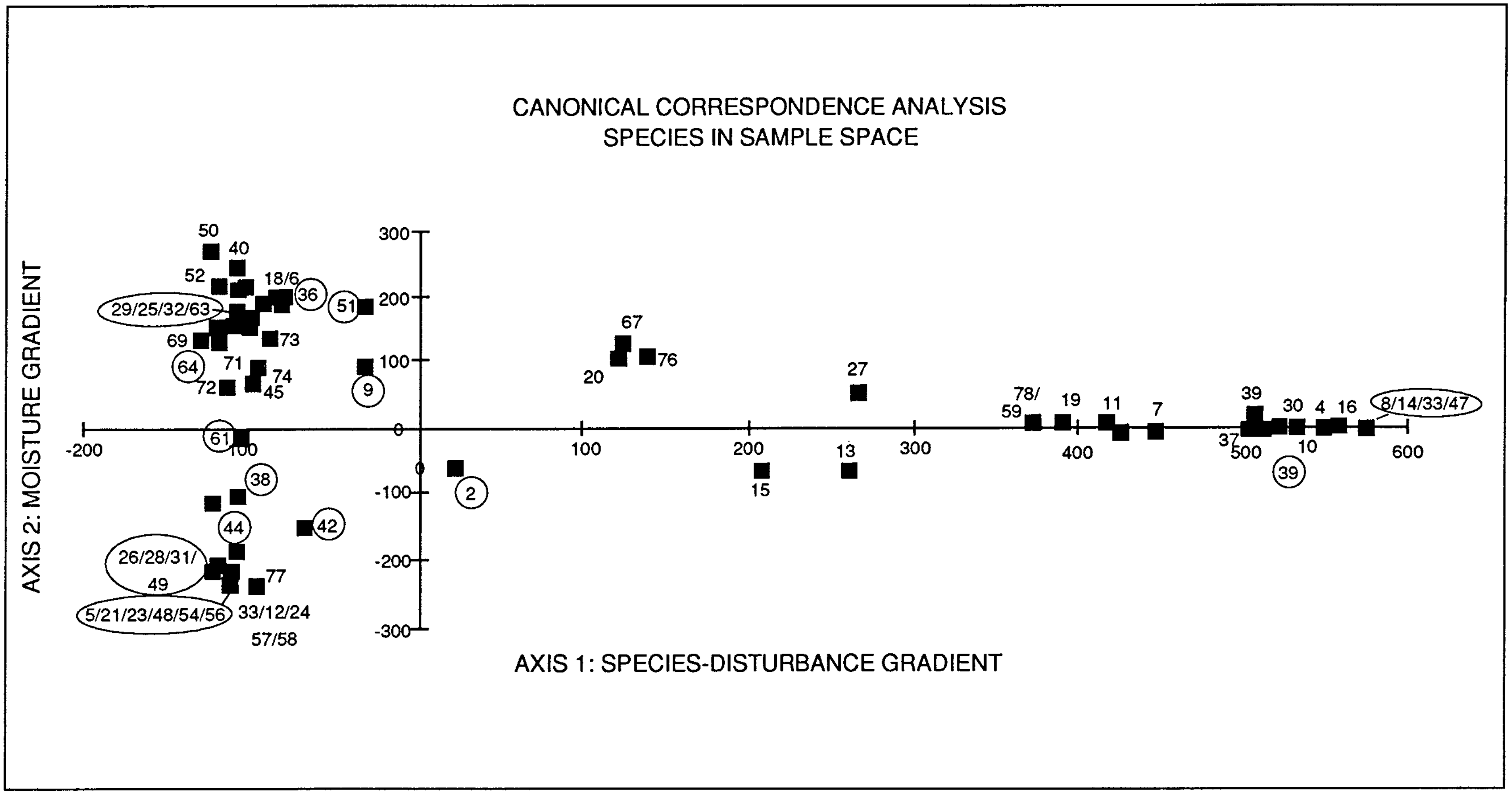


Figure 8. Canonical correspondence analysis—species in sample space

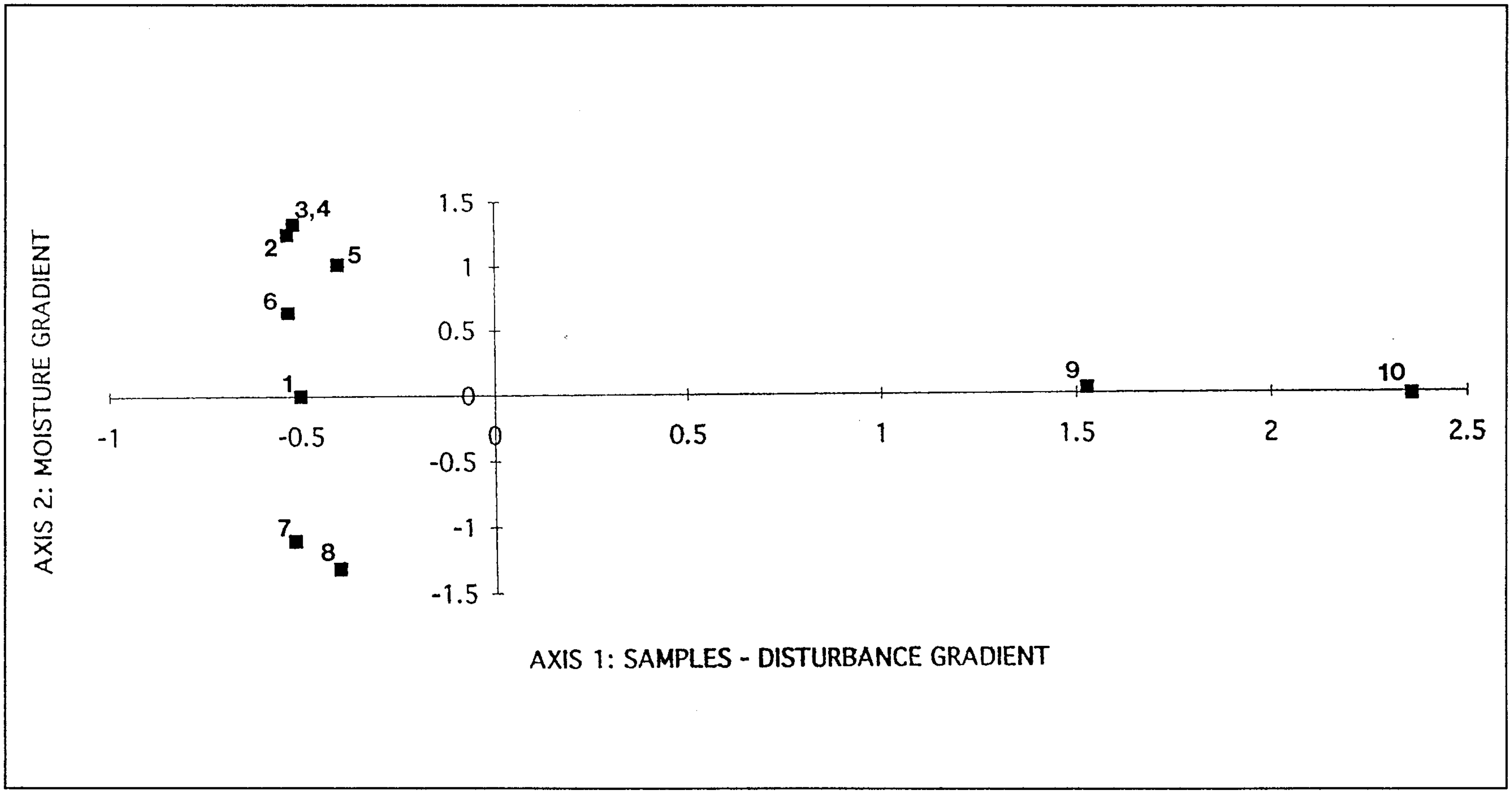


Figure 9. Canonical correspondence analysis—sample scores

site (Transects 7 and 8) from transects in the emergent area of the mitigation site. The negative side of the x-axis represents emergent wetland species; a moisture gradient is established along the first axis. The second axis is defined by separation of the reference area from the emergent mitigation site transects.

The species ordination is illustrated in Figure 8 and Table 5. Each number represents a species. The first axis is separated by *Baccharis, Cicuta maculata, Malva* sp., and *Raphanus* sp. (Transects 8, 14, 33, and 47). Also defining the positive side of the first axis are *Convolvulus* (16), *Antennaria* (4), *Brassica nigra* (10), *Lolium* sp. (30), *Picris echioides*, (39), *Phalaris tuberosa* (37), and *Rumex crispus* (50). These species are all dominant upland non-native species characteristic of the herbaceous upland cover type which is represented in the two long transects. *Scirpus acutus* (61) represents the left side of the first axis along with *Ammania coccinia* (2), both characteristic of dominant wetland emergent species occurring in both the reference and mitigation sites.

The second axis is ecologically interpretable, with a gradient of wetland species occurring on the positive side of the y-axis. *Lemna* (28), *Juncus* sp. (26), *Ludwigia peploides* (31), and *Rubus* spp. are in one group on the negative side of the y-axis; *Mentha arvensis* (35), *Carex* sp. (12), *Holcus* sp. (24), *Salix* sp. (57), and *Salix lasiolepis* (58) in another tight cluster; and *Apocynum* (5), *Epilobium glaberrimum* (21), *Juncus phaeocephalus* (23), *Rosa* sp. (48), *Salix* sp. 2 (54), and *Salix scouleriana* (56). The negative side of the y-axis includes species characteristic of the reference site. These include *Stachys* sp., *Salix lasiandra, Holcus* sp., *Carex* sp., and *Rubus* spp.

On the positive side of the y-axis, *Rumex crispus* (50), *Plantago* sp. (40), *Solanum americanum* (65), *Sagittaria latifolia*, (52), *Polygonum hydropiperiodes* (43), and *Typha angustifolia* (68) are included. These species represent the understory of subdominant emergent species in the mitigation area. The second axis effectively pulled out species occurring only in the reference site and species in the mitigation site, indicating a distinctive difference in species composition is occurring between the two sites. The first axis includes an upland non-native species component on the positive side characteristic of the gradient transects, a wetland/upland component on the negative side which is subsequently separated into the emergent mitigation areas and the reference site.

The soils data are ecologically difficult to interpret (Figure 10, Table 6). Soils samples were lumped by transect, rather than having individual soils samples for every vegetation quadrat. In the 1994 field sampling, the sampling procedure was changed to derive more interpretable results. Basically, the southeast side of the mitigation site (corresponding to piezometers 7 and 9) is separated in the upper left quadrant, Area 1 (the most northeast sampling location) in the upper right quadrant, the reference site samples in the lower quadrants, and the remaining emergent areas clustered in the middle. Area 1 is distinctive in that it is an area of high accretion. Areas 7 and 9 indicate significant erosion. In the reference area, Areas 8 and 11 are on the west side

Table 5
Multivariate Analysis

Species	x-axis	y-axis
Polygonum sp.	-67	-157
Polygonum hydropiperoides	-104	213
Polygonum hydropiperoides	-112	-188
Polygonum persicaria	-100	66
Populus fremontii	-98	205
Raphanus raphanistrum	573	-3
Rosa sp.	-124	-219
Rubus sp.	-114	-235
Rumex crispus	-126	267
Rumex pulcher	-34	189
Sagittaria latifolia	-121	217
Salix lasiandra	-98	-262
Salix sp.	-123	-117
Salix laevigata	-99	204
Salix scouleriana	-120	-225
Salix sp.	-98	-262
Salix lasiolepis	-98	-262
Sambucus mexicana	371	8
Samolus parviflorus	-98	205
Scirpus acutus	-107	-40
Scirpus californicus	-98	205
Scirpus mucronatus	-111	154
Setaria sp.	-130	130
Solanum americanum	-100	206
Stachys sp.	-98	-262
Taraxacum officinale	120	130
Typha angustifolia	-110	211
Typha domingensis	-113	159
Typha latifolia	-98	204
Typha sp.	-120	132
Verbena hastata	-114	60
Verbena sp.	-90	133

(Continued)

Table 5 (Concluded)		
Species	**x-axis**	**y-axis**
Xanthim strumarium	-98	88
Unknown *Lamiaceae*	-98	205
Unknown emergent	136	107
Unknown forb	-98	-250
Unknown *(Onagraceae)*	371	8

of the reference site; Area 10 is on the east side. Possible explanations for this separation include high Ca/Mg and Na in Areas 1, 11, and 8 on the positive side of the axis, and lower Ca/Mg and Na in Areas 7 and 9 on the negative side.

Woody Vegetation

1993

The species with the highest survival on the site are mule fat (*Baccharis vimineae*), California valley oak (*Quercus lobata*), California black walnut (*Juglans hindsii*), and Fremont cottonwood (*Populus fremontii*) (Table 7). Though California valley oak are abundant in numbers, their average height is only 14 in. The other species grow much more rapidly, with mule fat averaging 82 in., California black walnut averaging 46 in., and Fremont cottonwood averaging 77 in.

Overall, 62 percent of the planted area has live trees (mortality averaged 38 percent for the entire site); relative survival varies by location. Mortality on the site interior northeast corner is 75 percent; outside the levee is 43 percent. Mortality for the north side is 16 percent; mortality for the south side is 29 percent; mortality for the southwest side is 26 percent; mortality for the east site is 48 percent; mortality on the eastern island is 52 percent; and mortality in the southeast corner is 34 percent. Factors leading to high mortality include inadequate irrigation and competition from weeds. Many areas are heavily infested with star thistle.

1992

The area sampled experienced an overall 45-percent mortality the first year. Portions of the levees eroded, removing all planted woody vegetation in these areas. Woody species composition includes the following:

24 percent California valley oak (*Quercus lobata*)
22 percent California black walnut (*Juglans hindsii*)

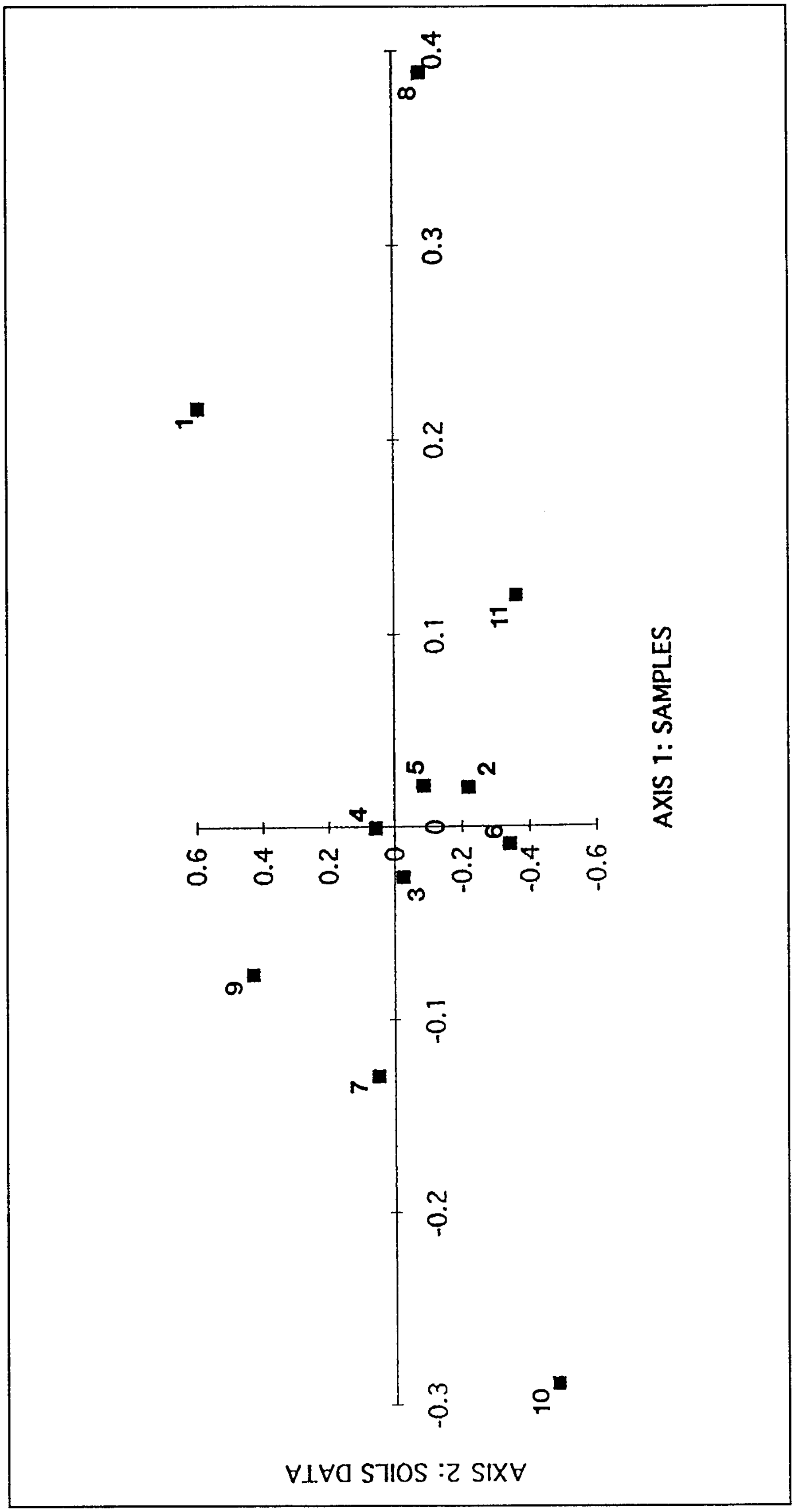


Figure 10. Canonical correspondence analysis—environmental scores

Table 6
Soils Analysis

Project Number	Area	Condition
1	NE mitigation	Accreting sediment
2	N mitigation	Accreting sediment
3	NW mitigation	Accreting sediment
4	NW mitigation	Accreting sediment
5	NW island	Eroding
6	E mitigation	Eroding
7	SE mitigation	Eroding
8	W reference	Stable
9	E reference	Stable
10	Center reference	Stable
11	Center reference	Stable

Table 7
Woody Vegetation

Species	Common Name	Family
Acer negundo	Box elder	Aceraceae
Aesculus californica	California buckeye	Hippocastanaceae
Aesculus rhombifolia	California white alder	Betulaceae
Baccharis vimiea	Mule fat	Asteraceae
Cephalanthus occidentalis	Buttonbush	Rubiaceae
Juglans hindsii	California black walnut	Juglandaceae
Platanus racemosa	California sycamore	Platanaceae
Populus fremontii	Fremont cottonwood	Salicaceae
Quercus lobata	California valley oak	Fagaceae
Quercus wislizenii	Interior live oak	Fagaceae
Salix goodingii	Black willow	Salicaceae
Salix laevigata	Red willow	Salicaceae
Salix lasiandra	Yellow willow	Salicaceae
Sambucus mexicana	Elderberry	Caprifoliaceae

22 percent	Red willow (*Salix laevigata*)
19 percent	Elderberry (*Sambucus mexicana*)
3 percent	California sycamore (*Platanus racemosa*)
2 percent	Yellow willow (*Salix laesiandra*)
1 percent	White alder (*Alnus rhombifolia*)
1 percent	Mule fat (*Baccharis vimiaea*)
1 percent	Black willow (*Salix goodingii*)
<1 percent	California buckeye (*Aesculus californica*)
<1 percent	Buttonbush (*Cephalanthus occidentalis*)
<1 percent	Fremont cottonwood (*Populus fremontii*)
<1 percent	Coast live oak (*Quercus agrifolia*)
<1 percent	Box elder (*Acer negundo*)

Soils

The soils throughout the project area are mapped as the Egbert series in the Solano County soil survey (Appendix B and Figure 2). However, there are virtually no undisturbed soils on the site. Levee construction and maintenance, past agricultural practices, and mitigation site excavation and construction have resulted in no undisturbed soil profiles remaining on the site.

The Egbert series consists of level to nearly level, poorly drained soils in basins. These soils formed in alluvium derived from mixed sources. The average annual temperature is 60 to 62 °F. The average annual rainfall is 16 to 18 in., and the frost-free season is 260 to 280 days. Elevation ranges from 5 ft below sea level to 10 ft above sea level.

In a representative profile, the surface layer is gray silty clay loam 31 in. thick. The substratum is mottled, gray silty clay loam that extends to a depth of more than 60 in.

Water Quality

Water quality data were taken four times during the year: August 1993, November 1993, March 1994, and April 1994.

Nitrate (NO3-N) (ppb) (see Figure 11)

Date	Mean	Max	Min
Aug 93	90	155	44
Nov 93	283	340	261
Mar 94	184	348	122
Apr 94	181	307	146
Sample Total	185	348	44

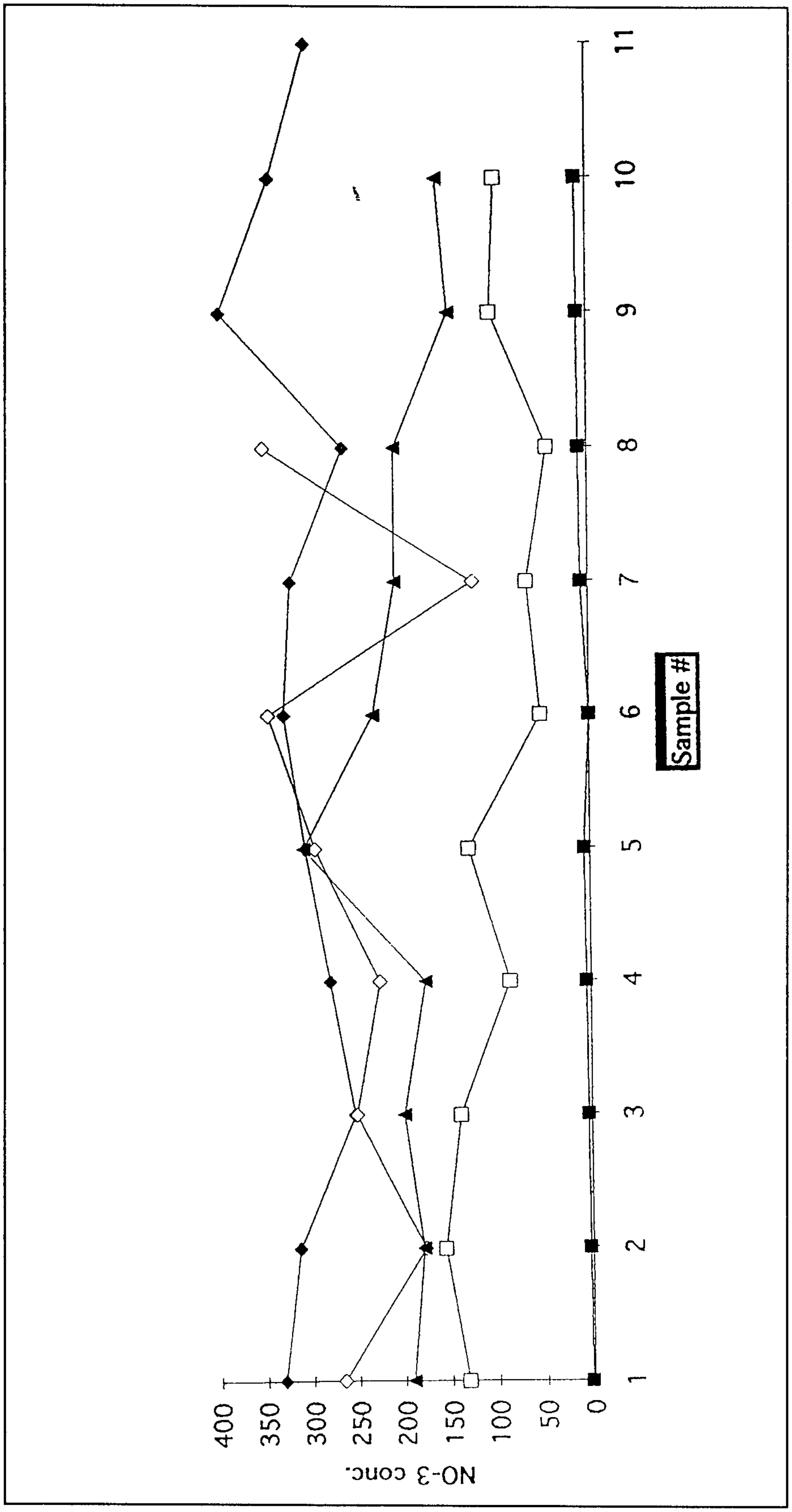


Figure 11. Water quality: NO3-N

Ammonia (NH4-N) (ppb) (see Figure 12)			
Date	**Mean**	**Max**	**Min**
Aug 93	30	63	23
Nov 93	48	65	33
Mar 94	127	224	70
Apr 94	54	83	23
Sample Total	65	224	23

Soluble Reactive Phosphorus (SRP) (ppb) (see Figure 13)			
Date	**Mean**	**Max**	**Min**
Aug 93	50	80	45
Nov 93	55	86	51
Mar 94	105	117	85
Apr 94	81	105	64
Sample Total	73	117	45

Nitrate levels are fairly high as ambient background water quality, which is to be expected from an open water source in an agricultural area. Differences between the mitigation site and reference site (samples 9, 10, 11, and 12) are not significant. Nitrate is not subject to immobilization by soil particles and is thus much more mobile in solution.

Ammonia levels are lower than nitrate levels. Ammonia may be absorbed by plants through their root systems or by microorganisms and nitrified to nitrates, converted back to organic matter, or immobilized on soil particles.

The active growing season begins in March and continues through other sampling dates. Vegetation is senescent during the November sampling period. This is when the highest nitrate levels occur, perhaps from the lack of plant uptake and release from senescent plant tissue.

Total Phosphorus (TP) (ppb) (see Figure 14)			
Date	**Mean**	**Max**	**Min**
Aug 93	80	132	31
Nov 93	73	107	45
Mar 94	111	177	13
Apr 94	144	166	122
Sample Total	94.5	177	13

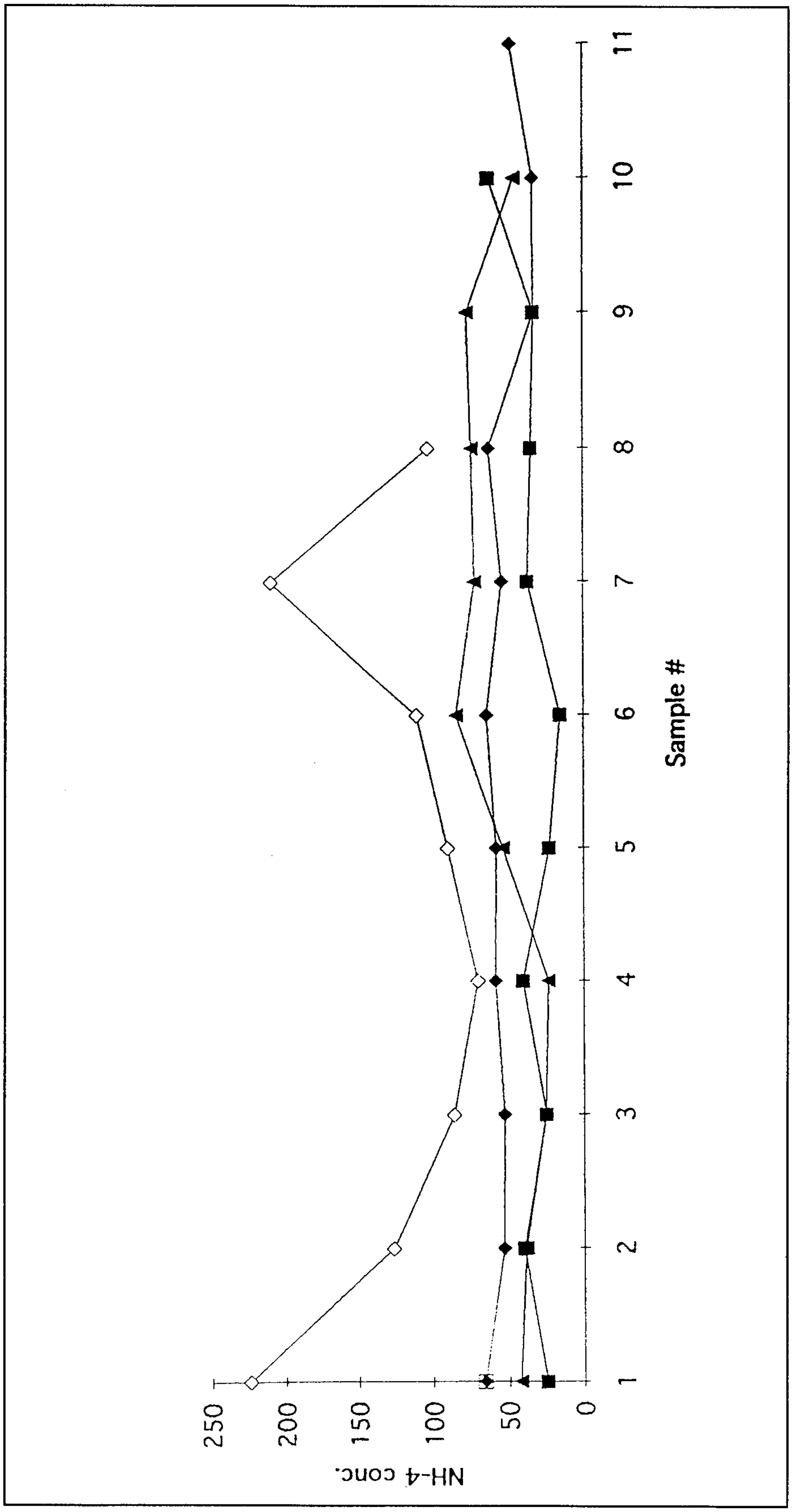


Figure 12. Water quality: NH4-N

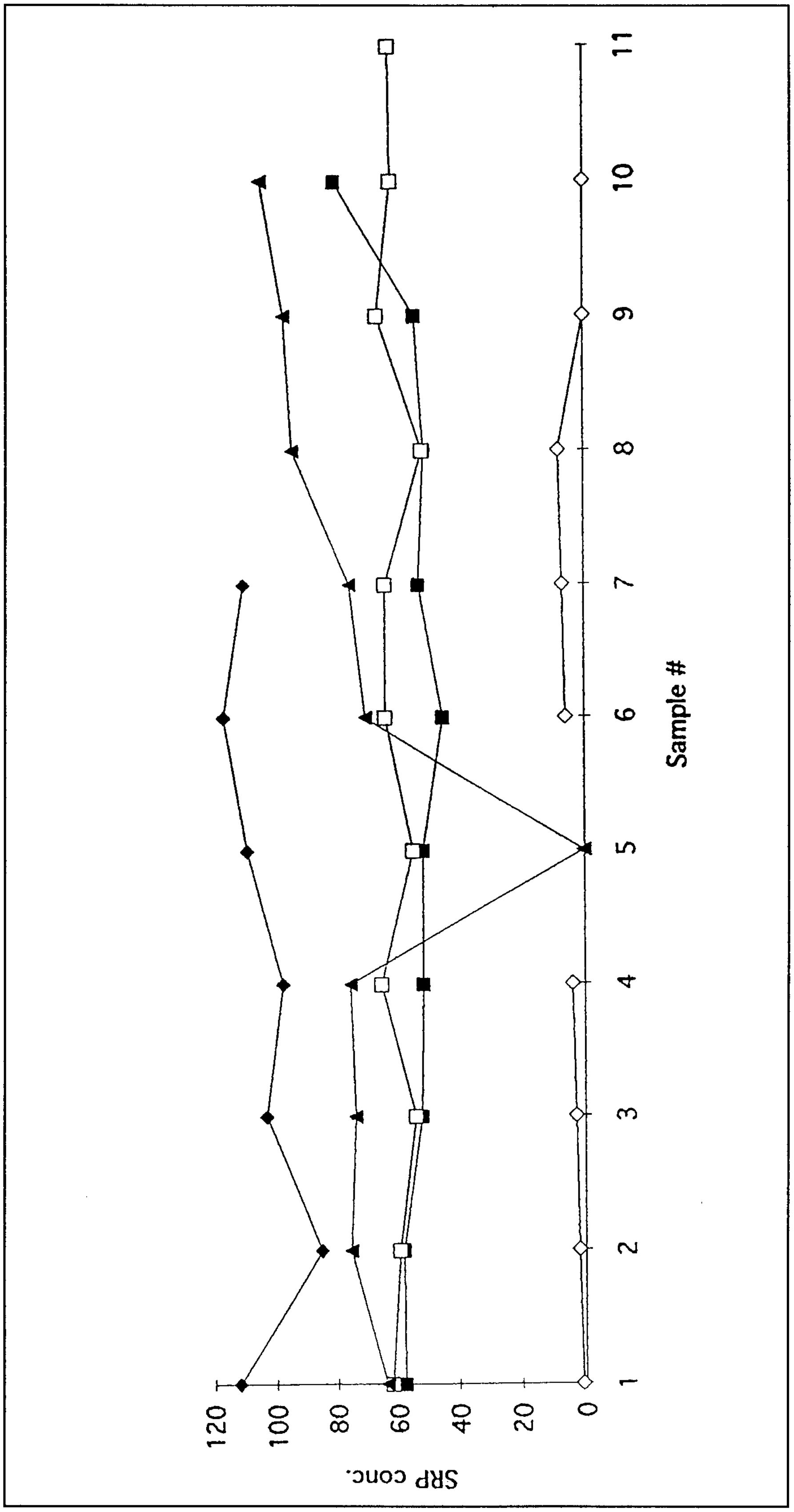


Figure 13. Water quality: SRP

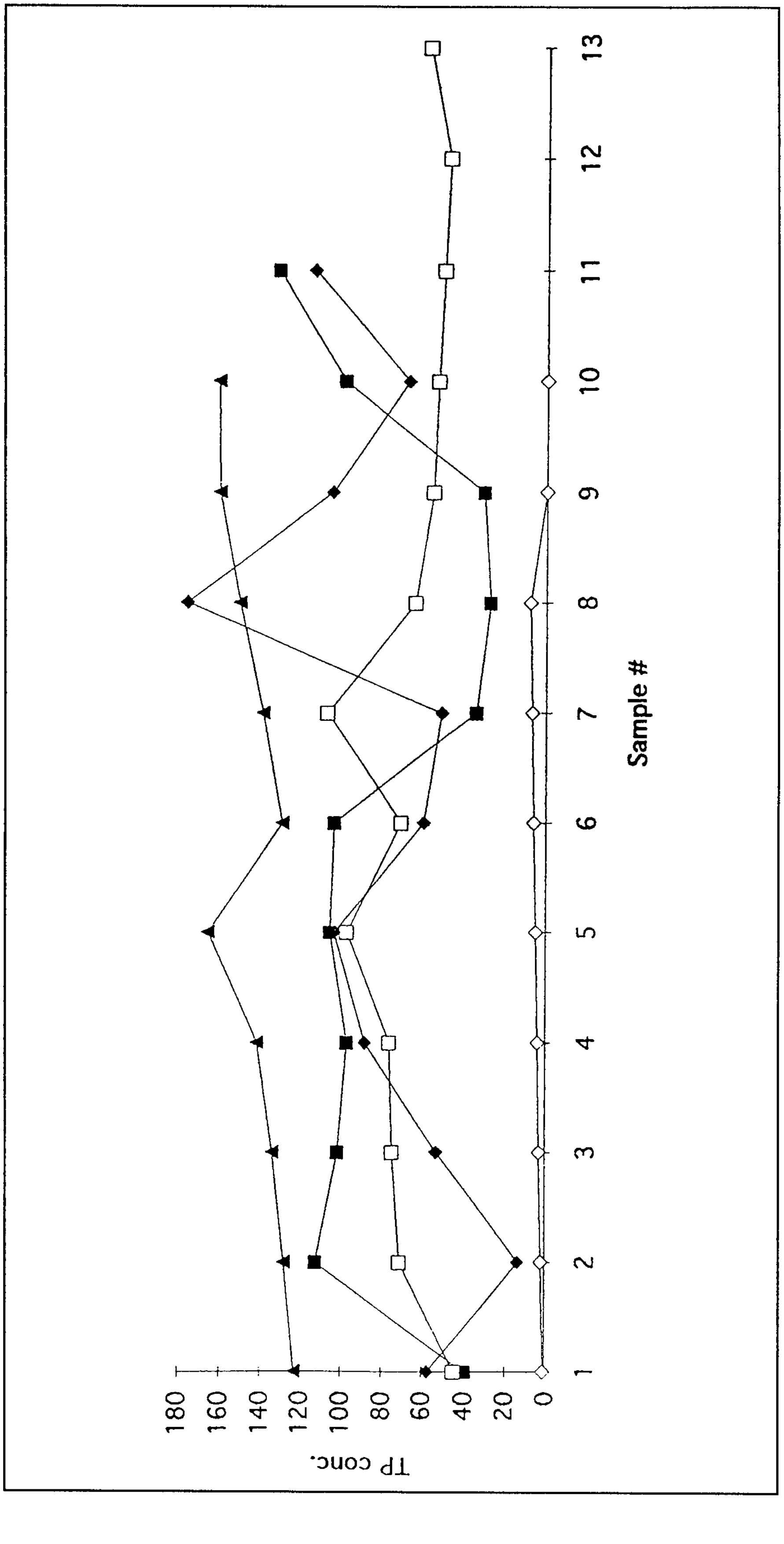


Figure 14. Water quality: TP

Despite a wide range of N:P ratios (with the optimum ratio often given as 10:1), Shaver and Melilo (1984) found that their freshwater marsh plants accumulated nutrients at an optimum N:P ratio of approximately 8:1 by mass. At Cache Slough, the ratio of nitrogen (NO_3 + NH_4) to soluble reactive phosphorus (which is available to plants) is 3.4:1. This means that nitrogen may be somewhat limiting. However, nitrate and ammonium levels are still fairly high and are able to support healthy plant growth and reproduction. There is no significant difference in measured levels of nitrogen and phosphorus between the mitigation site and reference area.

Hydrology

The following tidal information and fetch calculations were provided in the 1990 U.S. Army Corps of Engineers report on the Cache Slough/Yolo Bypass mitigation area.

Average high tide:	3.9 ft mean sea level (msl)
Average low tide:	0.1 ft msl
Average mean tide:	2.0 ft msl
Average extreme high tide:	5.1 ft msl (Dec/Jan)
	4.8 ft msl (June/July)

Maximum fetch wave heights across the basin were calculated at 1.67 ft; late summer winds from the northwest in August and September have the most erosive impact on the interior eastern levees.

Existing grade within the basin varies from 1 to 2.5 ft below msl. The Cache and Shag slough water levels range from 0 to 4 ft msl. Two weir sections of 150 lin ft with 3:1 slope are located at each slough to maximize tidal water circulation within the basin. The weirs are designed to have 100-percent exchange of water volume every 7 days.

Piezometer Data

Water level changes at the Cache Slough mitigation area are unpredictable because of seasonal fluctuations, tidal influence, and wind-driven tides. Flooding "pulses" that occur seasonally contribute the greatest fluctuation in high and low water levels (Figures 15 and 16). The emergent zone at the elevation in which the piezometers were installed is flooded on a daily basis, at least with the high high tide and often with the low high tide. The fine-textured clay soils result in slow water exchange at depth from the soil surface. When piezometers were installed, saturation occurred to only about 8 cm below the soil surface. Piezometers 1 and 2, located on the north cross levee, were under artesian pressure. Evidently the compacted fine-textured clays act as an aquaclude; when punctured, as occurred with piezometer insulation, groundwater discharge occurred.

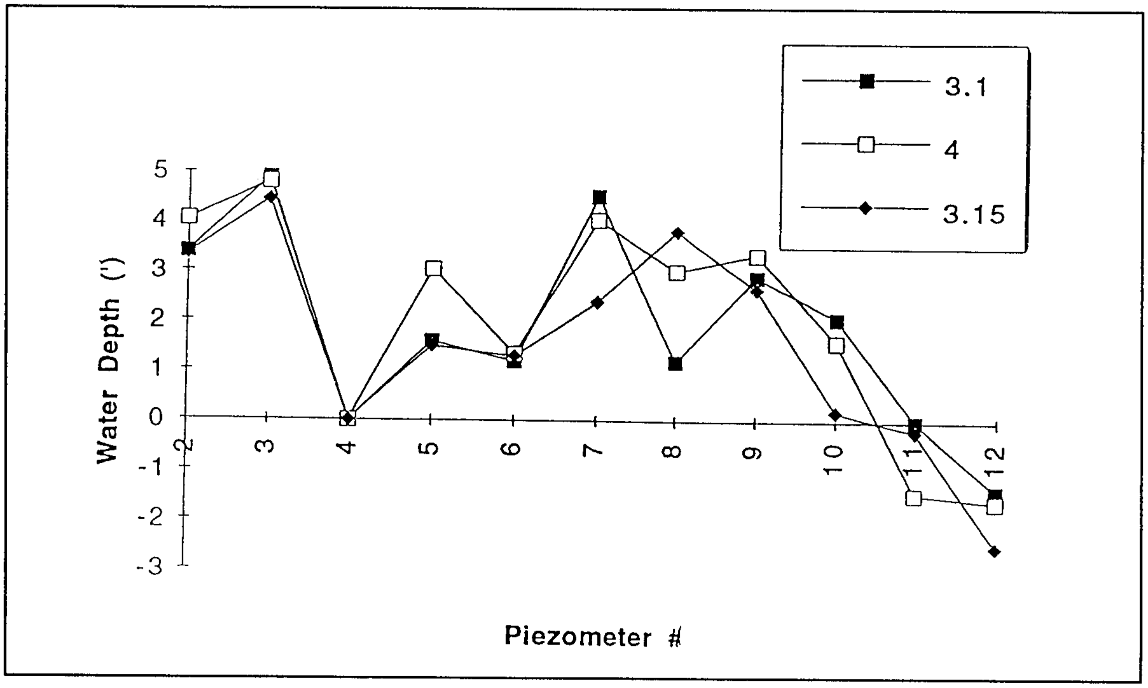


Figure 15. Piezometer data - 1993

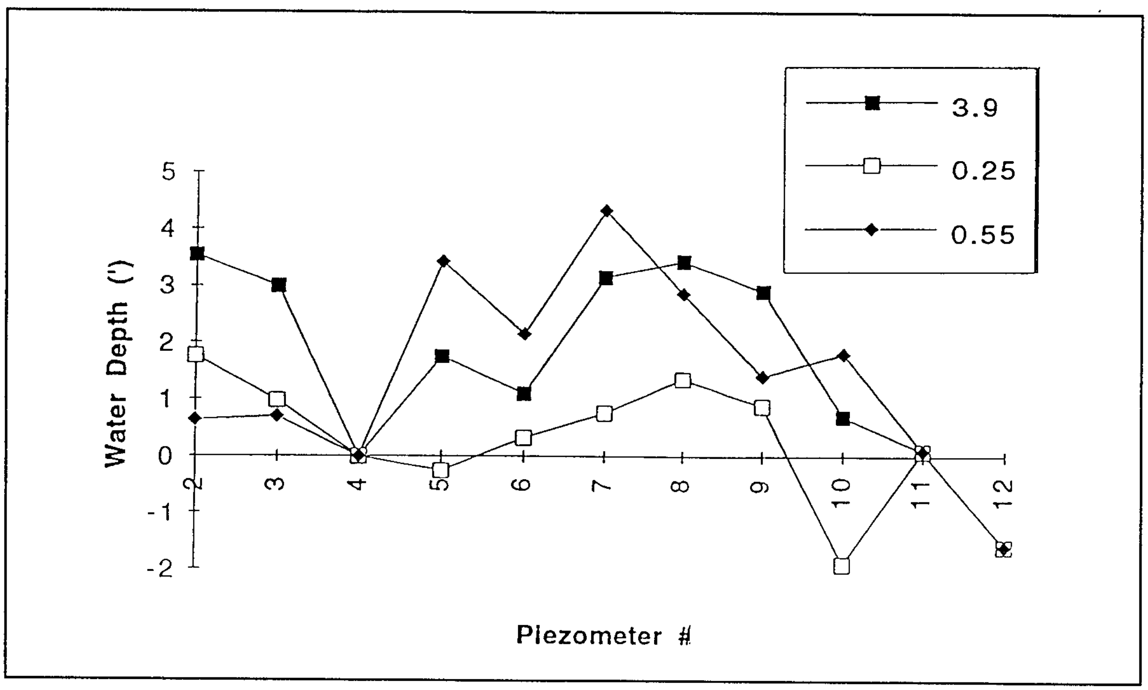


Figure 16. Piezometer data - 1994

Pulse-fed wetlands are often the most productive wetlands and are the most favorable for exporting materials, energy, and biota to adjacent ecosystems.

Sediment Budget

The site was sampled on August 11 from 0715 to 2230 hr. This tidal cycle was selected as a representative time period during the year to assess whether sediment was being imported or exported from the site.

Tidal Cycle			
Date	**Tide**	**Time**	**Datum**
8-11-93	Low low tide (-0.3)	0602	-0.165
8-11-93	Low high tide (4.8)	1219 (5.42 ft)	3.888
8-11-93	High low tide (2.9)	1716 (4 ft)	1.595
8-11-93	High high tide (6.0)	2241 (7.08 ft)	4.86
8-11-93	Low low tide (0)	0358	0.55

For the east branch, 520.19 g of sediment was measured coming into the site during the period of measurement (Figures 17-19). For the west branch, 3,203.88 g of sediment was measured entering the site (Figures 20-22). The low high, high low, and high high tides were measured; the low low tide was not included in the sampling period. The high volume of water exchanged between the high high and low low tides covered a significant time period which was not included. Less loss at the low low tide is anticipated, as there is less water leaving the site with less volume in the site. It is also expected that there is more volume of water and higher suspended sediment in the water column during high tides, when wind and wave action erodes fine-textured soils along the shore and resuspends sediment.

Therefore, it is estimated that sediment export from the site is equal to the sediment low during high low tide and this is subtracted from budget totals. Accordingly, -1,114.91 g from the sediment total from the east breach is subtracted, and -89.42 g from the sediment total from the west breach.

	East Breach, kg	West Breach, kg
	+0.520	+3.202
	-1.115	-0.089
Total	-0.595	+3.114

This results in a total sediment accretion for the 24-hr tidal cycle of +2.52 kg sediment.

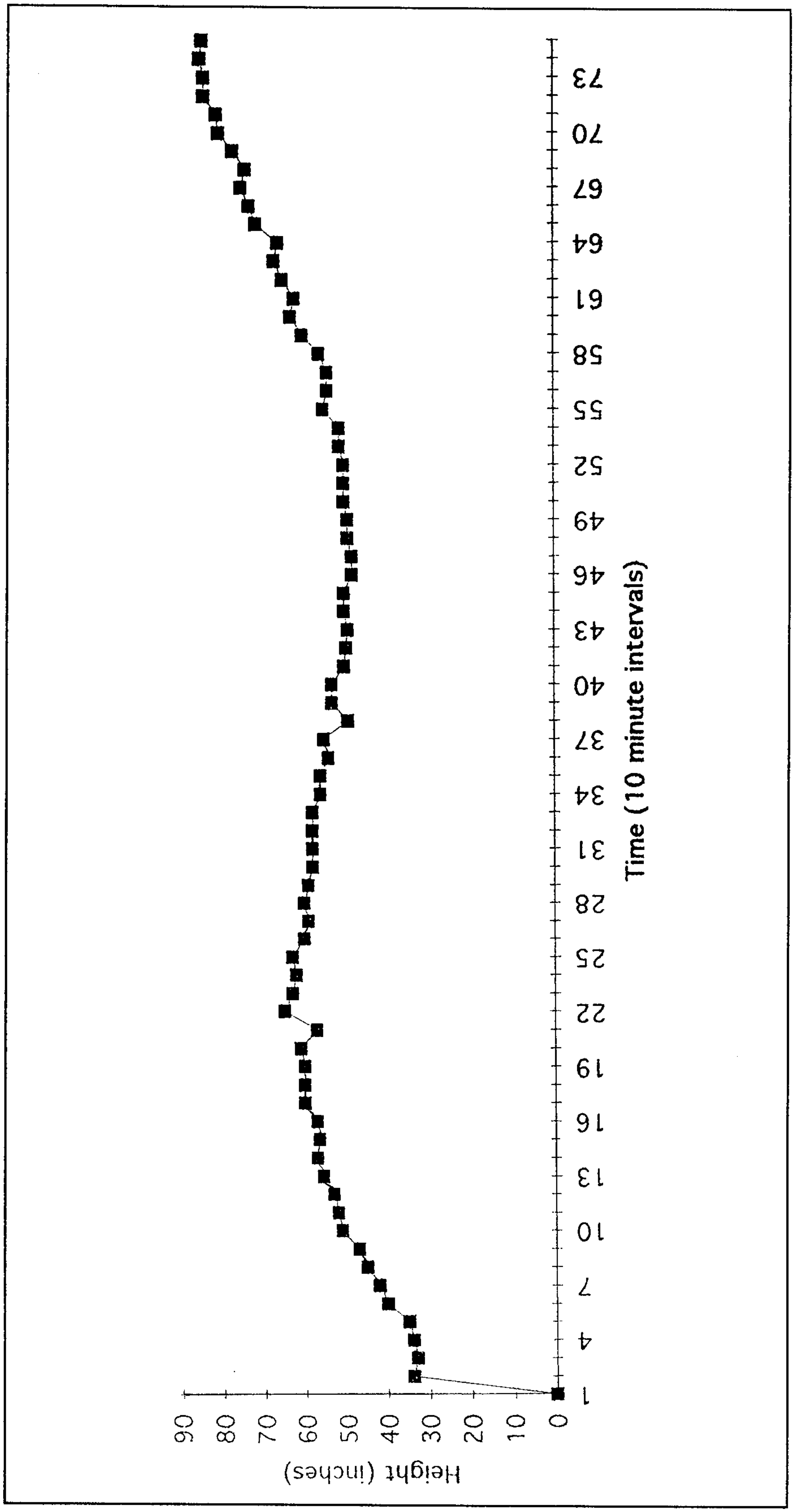


Figure 17. Sediment budget east breach—staff gauge height

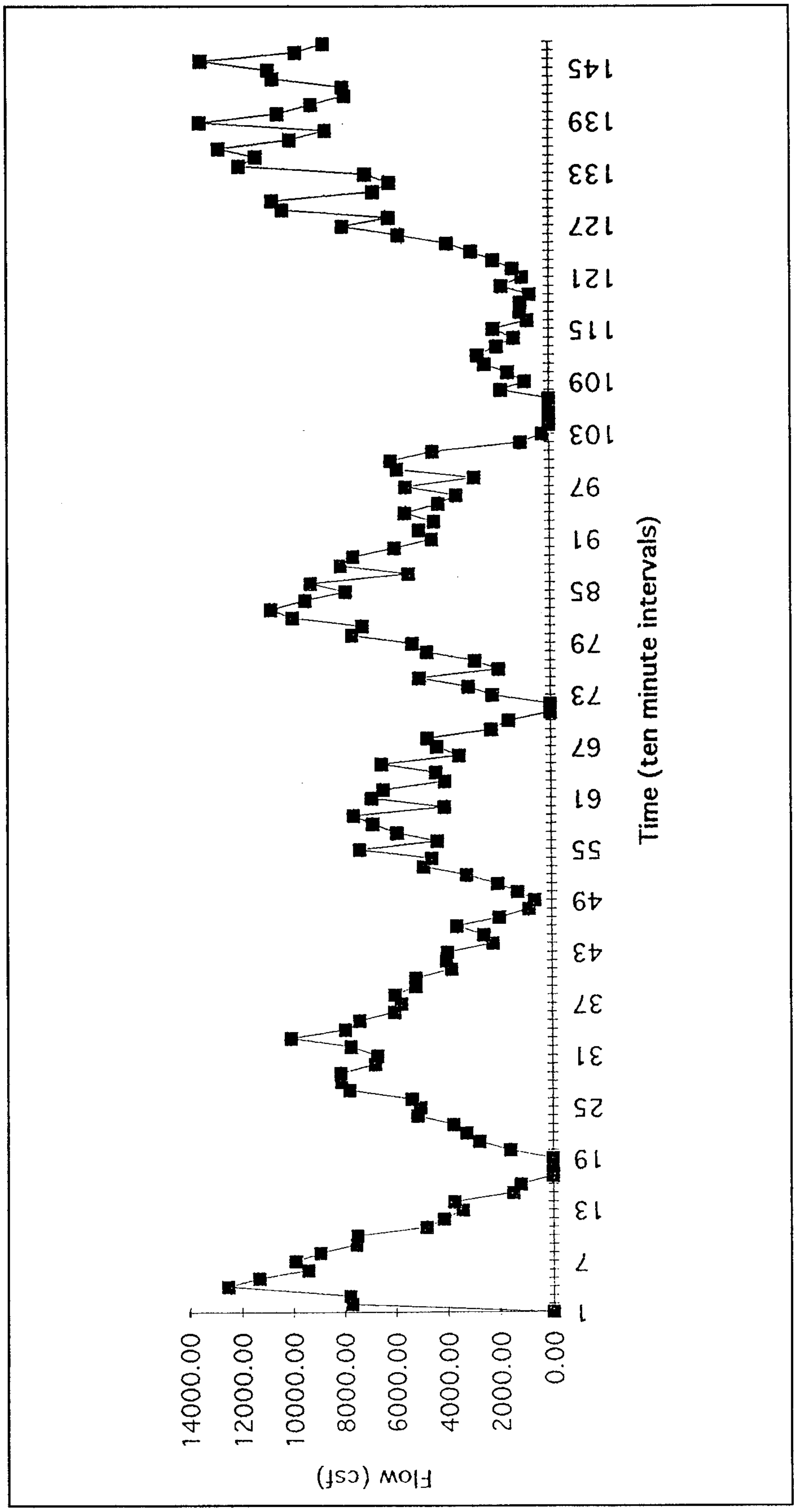


Figure 18. Sediment budget east breach—flow

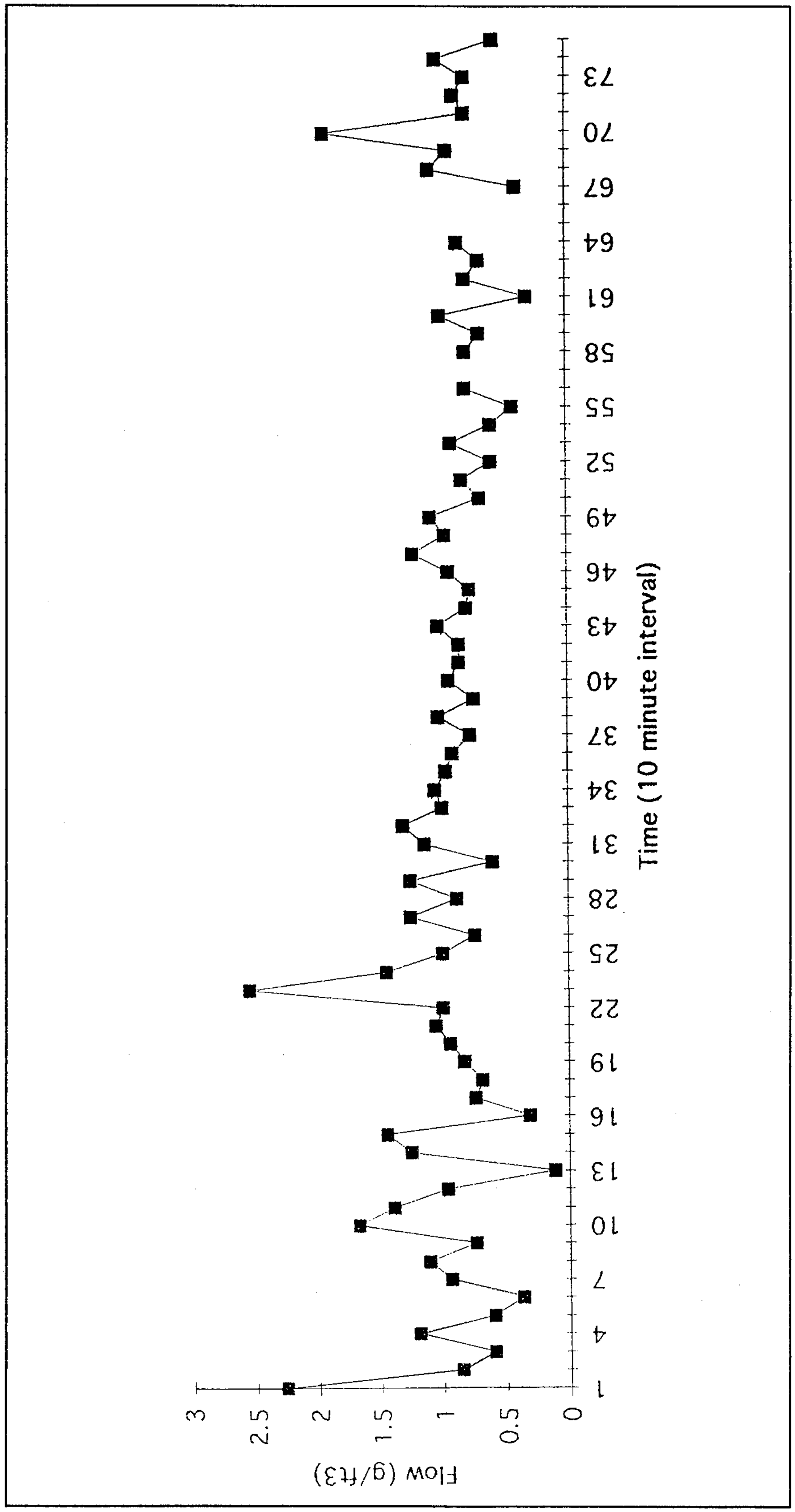


Figure 19. Sediment budget east breach—sediment/volume/time

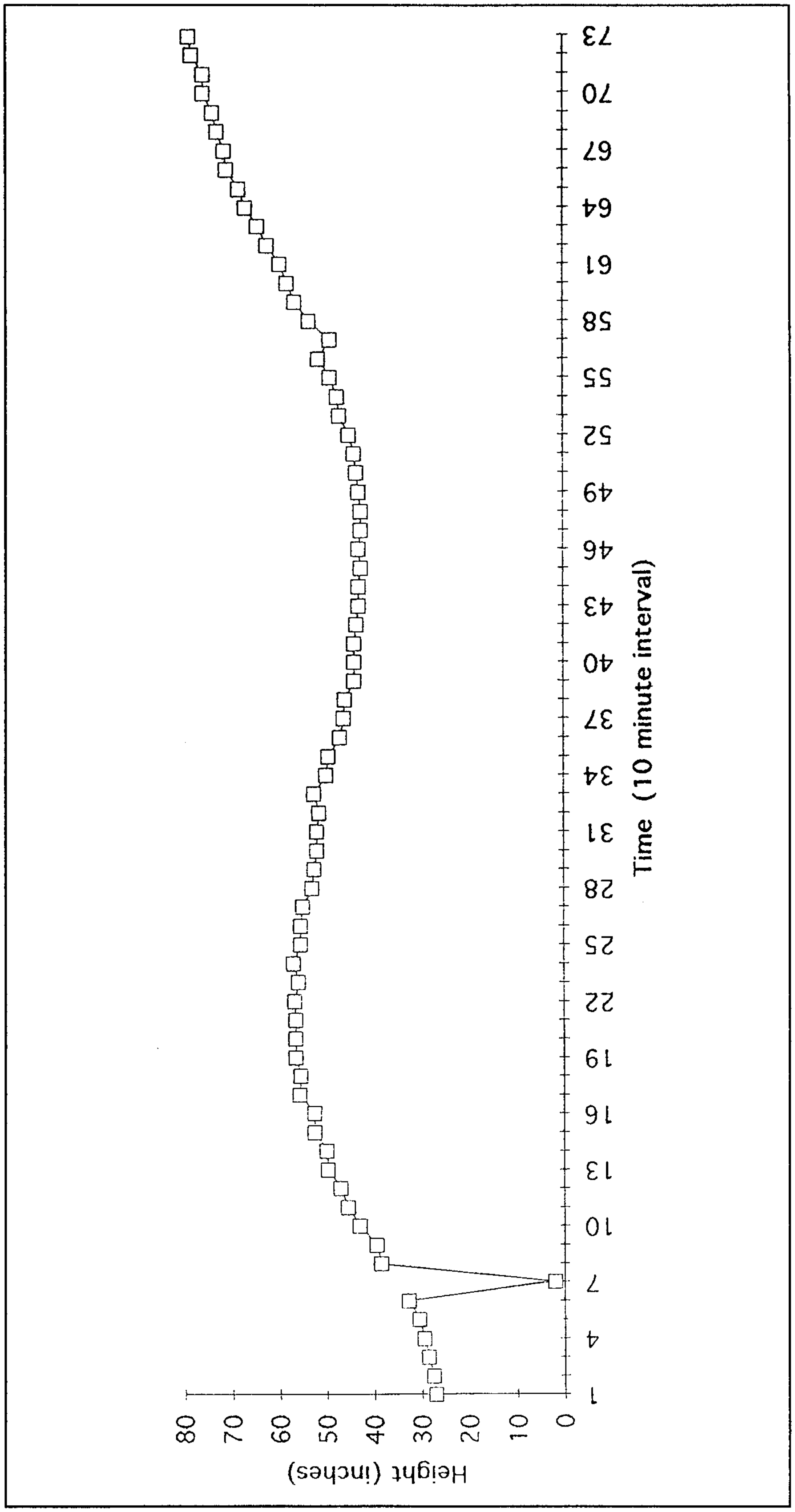


Figure 20. Sediment budget west breach—staff gauge height

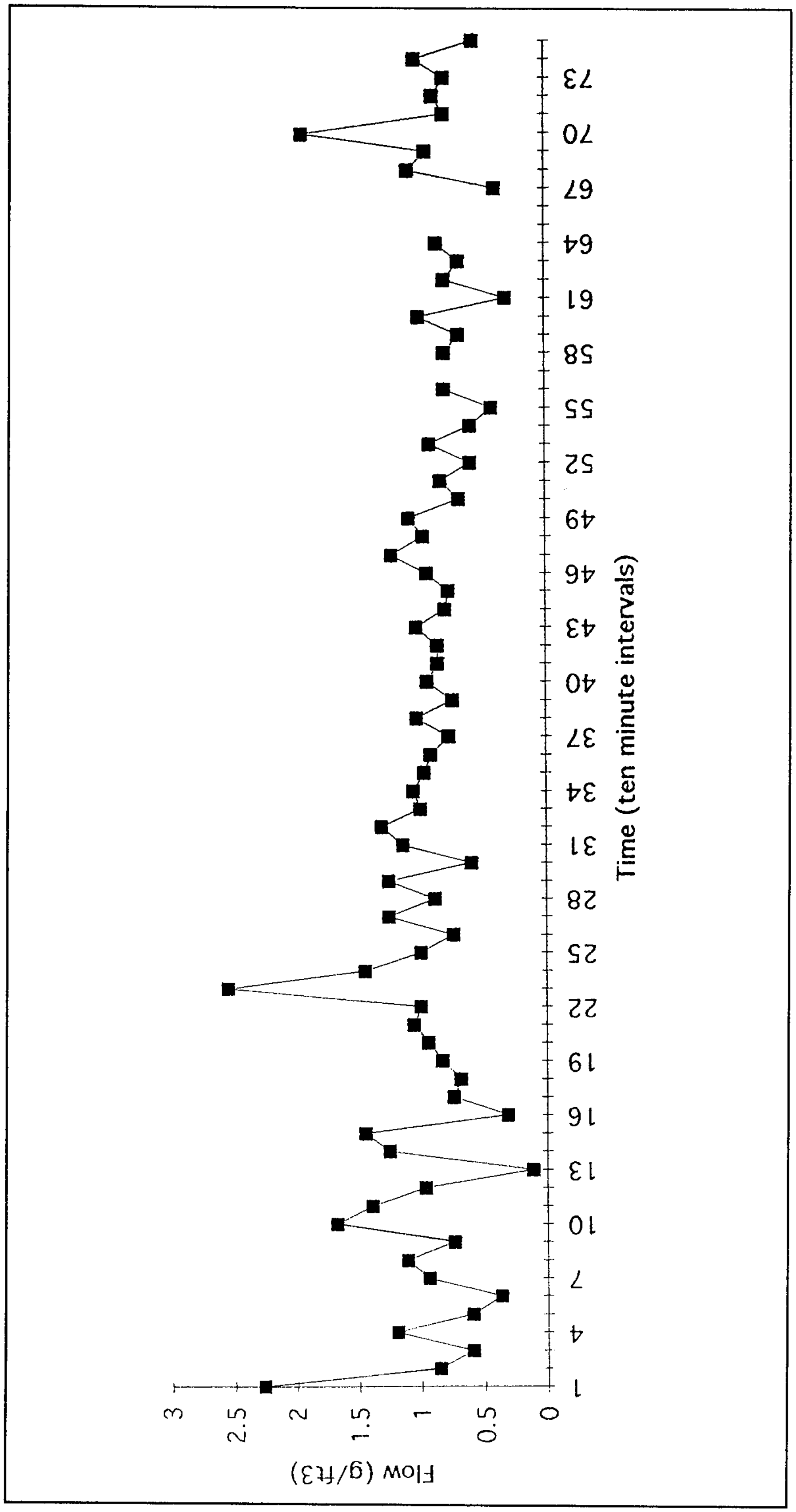


Figure 21. Sediment budget west breach—flow

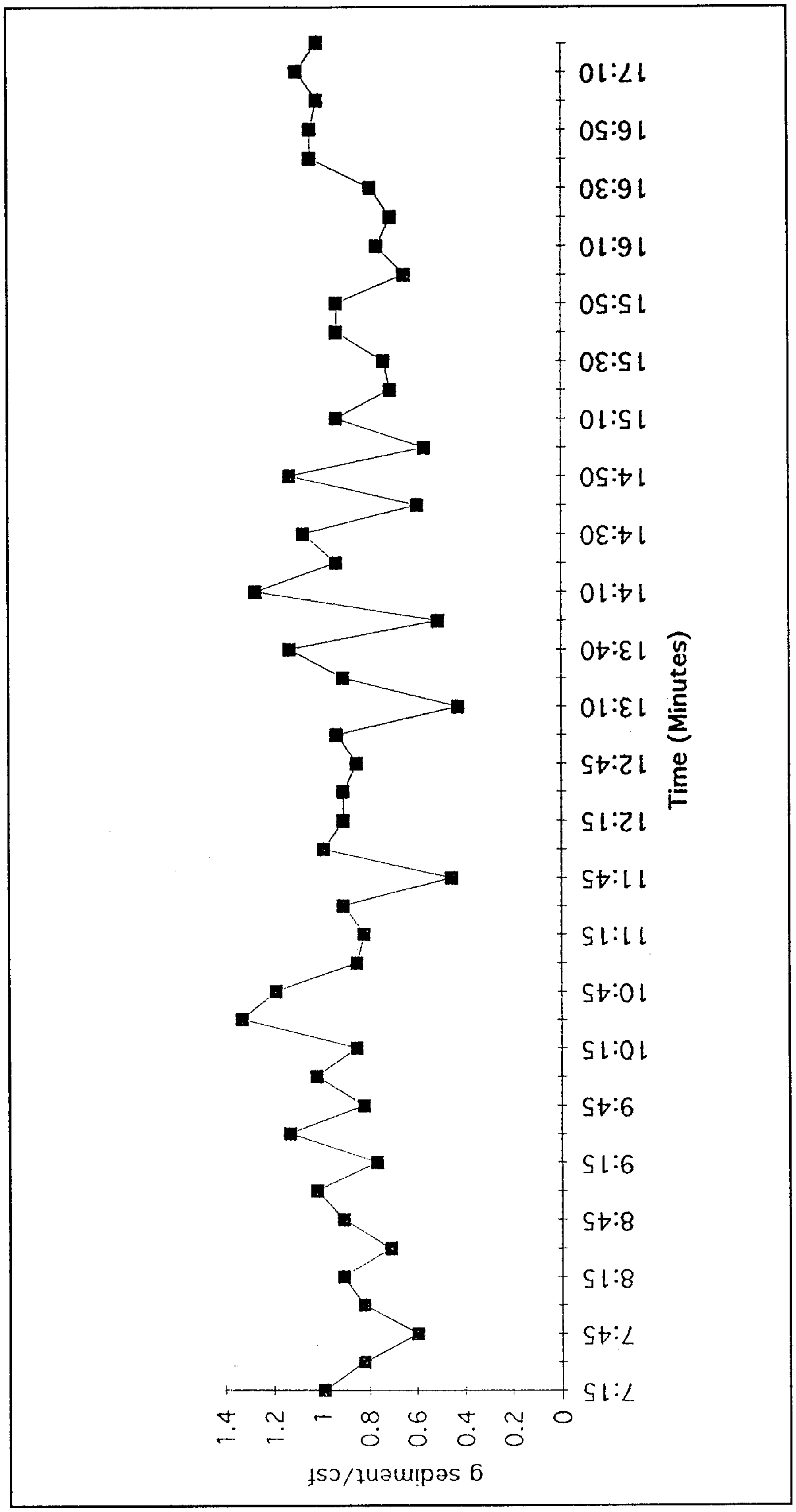


Figure 22. Sediment budget west breach—sediment/volume/time

It is interesting to note that there is a net export of sediment on the east side (-0.594 kg per 24-hr cycle) and a net import on the west side (+3.114 kg/24-hr cycle). Prevailing summer winds blow from west to east, so it is predicted that more sediment comes in the west side and erodes on the east side.

As water pillows on the west breach, some tends to move northward. As water velocities reach the wind speed at the cross levee on the northern portion of the site, velocities slow and sediment settles out. Of the 22 (out of 200) oranges found on the site, all were thrown out on the east side, and all were found north of the breach. The fact that 11 percent of the oranges remained onsite gives some idea of the exchange rate, at least for surface hydrology, for the site for one tidal cycle.

The location of the oranges would suggest that sediment is accreting on the point bars of the island and on the north side of the site. No oranges were found south of either breach, and at this time there is no evidence at very low tides of sediment accretion in these areas. The majority of accumulation of flotsam and jetsam tends to accumulate on the northern boundary of the site.

According to Dr. Ray Krone,[1] representative values for the year do not tell much about long-term values of sediment accretion at the site. After years of studying the hydrology and hydraulics of the delta, Dr. Krone has determined that episodic events form sedimentation processes, and that these are not predictable.

August was chosen as a representative month to characterize background sediment conditions. This time of year was selected because very high volumes of suspended sediment would not be in the ambient water due to runoff or high flow conditions. If sediment is indeed accreting in the north side of the site, the rate will not be constant over the year as a predictive value into the future. Strong winter storm winds come from the north. Site conditions preclude progressive or uniform sediment accretion; the combination of delta winds, 72 percent of the site being open water, fine-grained sediment, and shallow bathymetry will result in continuous resuspending of sediment and some erosion. Marsh-building processes do appear to be occurring on the northern portion of the site; rate of sedimentation cannot be assessed by this report.

The best analysis of the marsh will probably be to continue taking aerial photographs at the same time of year during low tide; sedimentation and revegetation can then be calibrated.

If a predictive assessment for sedimentation rates and marsh-building processes is desirable for this site, this data could be used to develop a more refined model for the site. A key factor, year-round wind direction and velocity, would have to be calibrated into the model.

[1] Personal Communication, 1994, Dr. Ray Krone, Hydrologist, University of California, Davis, emeritus, Davis, CA.

4 Conclusions

Mitigation Site

The Cache Slough mitigation site was created with the following goals and objectives:

a. The integrity and stability of the cross levee and bypass levees will be protected and not overtly compromised by enhancement alternatives.

b. The wildlife habitat to be targeted for design will be palustrine forest cover.

The mitigation site is proposed for use as a mitigation bank for offsite mature forested riparian habitat. The mitigation area will be used as a bank for impacts from future bank protection work or other flood control improvements in the Sacramento-San Joaquin Delta. Vegetation composition has not changed significantly since 1992. Areas of emergent vegetation have increased significantly, particularly on the south side of the site. The east side and the islands continue to erode and have not increased in area. The north side revegetated rapidly and is increasing in area and species diversity over time. Structural diversity through natural revegetation of woody species such as willows is also occurring.

Value and function compensation through construction of this mitigation site include the following:

a. *Levee stabilization.* This value is high, as the site was initially engineered primarily for this purpose.

b. *Fisheries habitat.* This habitat appears to be good, with a diversity of fish species occurring on site which are characteristic of the delta. The delta smelt, a Federal- and state-listed threatened species, appears abundant within the mitigation area.

c. Wildlife habitat.

(1) *Open water.* Open water is the major habitat type onsite, comprising 125.67 acres, or 71 percent of the site. Species dependent on open-water habitat such as swallows, egrets, heron, shorebirds, and gulls have been observed using this site for feeding.

(2) *Emergent wetland habitat.* Emergent wetland vegetation provides 9.54 acres of habitat value, or 5 percent of the site.

(3) *Palustrine scrub-shrub and riparian habitat.* Areas of riparian habitat cover 13.45 acres, and upland shrub (primarily blackberry) covers 6.01 acres. This cover type comprises 11 percent of the site. Vegetation on the levees surrounding the study site has been removed using burning and herbicide application. Existing levee vegetation provides an island of habitat in the Sacramento delta. In particular, upland gamebirds (particularly pheasants), passerine birds, and small mammals were observed in this habitat type. These habitat islands may be very important for migratory species, particularly in light of the fragmentation and elimination of the majority of riparian corridors in California.

(4) *Forested riparian habitat.* Habitat quality for species dependent on this plant community type is poor at this time. Since this is a primary goal of the mitigation, the functional replacement of this type is very important to achieving success. Approximately 13.45 acres are planted with riparian species, and some of the cottonwoods onsite are 18 ft tall. Over time, this type is likely to increase onsite.

d. Water quality. The site appears to be accreting sediment in the northern areas of the site. Sedimentation rates are unknown. Nutrient levels in the site are consistent with ambient water quality in the surrounding water bodies, Cache Slough and Shag Slough. Because of frequent flushing and flow-through characteristics of onsite hydrology, eutrophication and stagnation are not problems. Limited transformation is possible due to low plant cover on the site, active erosion limiting revegetation establishment, and an extremely dynamic and pulsing hydrologic system. N:P ratios are often described as optimum between 10:1 and 8:1. At Cache Slough, the ratio of nitrogen (NO3 + NH4) to soluble reactive phosphorus (which is available to plants) is 3.4:1. This means that nitrogen may be somewhat limiting, and that if nitrogen were applied, additional growth could result. However, nitrate and ammonium levels are still fairly high and able to support healthy plant growth and reproduction. There is no significant difference in measured levels of nitrogen and phosphorus between the mitigation site and reference area.

e. Sediment budget. When initiating the study of suspended sediment over a tidal cycle, it was not known whether sediment was primarily accreting or eroding from the site. It was found that a daily flux of sediment is occurring; total sediment accretion for one tidal cycle (24-hr period) is 2.52 kg sediment. It is interesting to note that there is a net export of sediment on the east side (-0.595 kg/24-hr period) and a net import on the west side (+3.1 kg/24-hr period). Prevailing summer winds blow from west to east, consistent with this finding.

As water pillows on the west breach, some tends to move northward. As water velocities reach the wind speed at the cross levee on the northern portion of the site, velocities slow and sediment settles out. All of the 22 (out of 200) oranges found on the site came from the boat located at the east breach; all were found north of the breach. The fact that 11 percent of the oranges remained onsite gives some idea of the exchange rate (at least for surface hydrology) for the site for one tidal cycle.

From analysis of aerial photographs, qualitative observations onsite, and the location of the oranges, it appears that sediment is accreting on the northern portion of the site and on point bars leeward of the islands. No oranges were found south of either breach, and there is no evidence at extreme low tides or from the aerial photographs of sediment accretion in these areas. The majority of flotsam and jetsam tends to accumulate north of the breaches. Sediment appears to be exported south of the breaches.

Site conditions preclude progressive or uniform sediment accretion. Two open breaches, daily flushing of the basin, 72 percent of the site being open water, high winds, long fetch, shallow bathymetry, and fine-grained substrate all contribute to continuous resuspension of sediment and some erosion. Marsh-building processes are occurring and do correlate with sedimentation and revegetation of the site. The rate of sedimentation cannot be assessed by this report.

The accretion pattern and change of bathymetry are questions to be addressed during the next field seasons. By placing a grid of staff gauges around the site, it will be possible to determine accretion and erosion rates. Existing data show that there is a net inflow of sediment to the site. Both sides are importing sediment, and one is importing more than the other side. The next step is to determine the spatial pattern of marsh evolution. Over time, this provides valuable information on marsh-building processes for restoration and mitigation. Sediment distribution rates may provide a rating system for candidates for restoration/mitigation based on rapid sediment accretion. Determining the pattern of sediment influx and revegetation may allow some predictive capability for determining the successful replication of wetland function (succesful restoration).

f. *Streambank stabilization.* Because of prevailing winds and long fetch, the shoreline is highly erosive. Fine-grained, unconsolidated sediment such as clay is particularly prone to erosion. Recent erosion control measures have reduced sediment and bank loss due to erosion, although erosion continues to occur at the site. The windward side of the islands, west side of the east levee, and southern shoreline are most prone to erosion. Vegetation tends to increase during stable periods and decrease during windy periods (late summer and winter). Prior to 1994, the same general area was vegetated from year to year; after erosion control measures were installed in 1993, the highly erosive area appears to be more stabilized, thus largely maintaining the same general area year to year. Areas north of the breaches are accreting sediment and are relatively stable.

Piezometers were surveyed in with well heights taken from the ground surface to the top of the piezometer. Measurement of the well height through the period of record has resulted in no detectable change in soil surface. Therefore, no significant subsidence or erosion of the ground surface was detected in these areas through the period of measurement.

g. *Flood detention or desynchronization.* The detention capability of the site is extremely poor because the catchment basin is open to continuous flow. In addition, vegetation establishment onsite is inadequate to slow flood velocities or provide a detention capacity (71 percent of the site is open water).

h. *Persistence on the landscape.* This value is poor. The levees were initially abandoned and the cross levee constructed because of difficulties maintaining levees. Estimates by the Corps of Engineers predict a 20-year expected longevity of external levees. Erosion occurred very rapidly the first year after construction; erosion control measures implemented in 1993 and 1994 have helped to stabilize the west levee. Riparian vegetation external to the levees provides a bioengineering function, further contributing to stabilization of the levees.

One of the project goals was establishment of forested riparian habitat; the longevity of the site is anticipated to be less than the time required to establish mature riparian forest. However, interim fish and wildlife habitat values will be obtained from the site. Predictions of revegetation, marsh-building processes, and levee stability are not available at this phase of project monitoring.

i. *Achievement of regional mitigation/restoration objectives.* In 1850, the year California became a state, there were approximately 5 million acres of permanent, seasonal, and tidal wetlands. It has been estimated that these wetlands have been reduced by over 90 percent to approximately 450,000 acres statewide (Frayer et al. 1989). According to Katibah et al. (1984), only 102,000 acres of riparian forest remain in the Central Valley today (800,000 acres were estimated in 1848). Of

these areas, only 53,000 acres were identified as mature riparian forest; virtually no pristine or presettlement condition remains. Accordingly, re-establishment of mature riparian forest and associated scrub-shrub and emergent wetlands is an appropriate goal in a watershed and regional context.

j. *Succession and revegetation.* The mosaic of wetland and riparian communities in the Central Valley is hierarchical in both space and time. Active channels carry streamflow varying from peak flood events to seasonal low flow and longer term drought conditions. During floods, fluvial deposition of mainstream sediments adjacent to active channels creates floodplains. In addition, tidal exchange carries sediment loads in or out of a site, depending upon site conditions.

The hierarchical organization of drainage basins is based on functional relationships between valley landforms and the processes that create them (Fressell et al. 1986; Hanson et al. 1990; Liu et al. 1992). Processes operating at one scale can affect geomorphic dynamics and structure at other scales. Watershed effects in headwaters or tributaries, or through mining groundwater aquifers, have significant effects downstream. Within this hierarchical system, spatial scales are consistent with the physical mechanisms responsible for landform change.

Riparian plant communities reflect histories of both fluvial disturbance from floods and the non-fluvial disturbance regimes of adjacent upland areas. Magnitude, frequency, and duration of floods diminish laterally away from the active channel. The development of riparian vegetation reflects disturbance regimes and flooding dynamics. Highly dynamic areas, such as those susceptible to high frequency flooding, are characterized by younger stands or often shrubs. Wind-dispersed willow, alder, and cottonwood are often first established onsite. Table 8 includes a list of plant species found at the site.

Cache Slough and other sites throughout the Central Valley are characterized by channel dredging, levee construction, and agricultural lands with maintained drainage ditches and intensive management with a high percentage of weedy exotic plant species. Hydrarch succession is unlikely to progress with any resemblance to presettlement condition. In addition, maintenance procedures on levees often involve systematic vegetation removal, particularly of the deeply rooted woody species. Herbaceous vegetation is treated with herbicide and burned.

Willoughby and Davilla (1984) compared tidal streambank flora to riparian woodland and annual grassland communities in Solano County. The major ecological factor influencing the distribution of plants in the intertidal zone of the study area is elevation with respect to tide levels. The highest floral diversity occurred in the riparian woodland community (78 species), followed by the tidal streambank community (49 species), and annual grassland community (38 species). The riparian woodland contained 37.2 percent introduced

Table 8
Plant Species List

Species	Origin
Aceraceae	
Acer negundo var. *californicum*	Native
Apiaceae	
Ammi visnaga L.	Non-native
Hydrocotyle verticillata Thunb.	Native
Alismataceae	
Alisma plantago-aquatica L.	Native
Sagittaria latifolia Willd.	Native
Asteraceae	
Antennaria spp.	
Aster chilensis Nees	Native
Baccharis salicifolia (Ruiz Lopez & Pavon) Pers.	Native
Bidens laevis (L.) Britton, Stems & Pogg	Native
Centaurea solstitialis L.	Non-native
Circium vulgaris Ten.	Non-native
Cotula coronopifolia L.	Non-native
Hieracium spp.	
Lactuca serriola L.	Non-native
Picris echioides L.	Non-native
Taraxacum officinale Wiggers.	Non-native
Xanthium strumarium L.	Global
Betulaceae	
Alnus rhombifolia	Native
Brassicaceae	
Brassica nigra (L.) Koch	Non-native
Lepidium latifolium L.	Non-native
Raphanus spp.	
Caprifoliaceae	
Sambucus mexicana C. Presl.	Native
Convolvulaceae	
Calystegia sp.	
Convulvulus simulans Perry	Native
Cyperaceae	
Cyperus eragrostis Lam.	Native
Cyperus laevigatus L.	Native
Eleocharis macrostachya Britton	Native
Scirpus acutus Bigelow var. *occidentalis* (S. Watson) Beetle	Native
Scirpus americanus Pers.	Native
Scirpus californicus (C. Meyer) Steudel	Native
Scirpus mucronatus L.	Non-native
Fabaceae	
Melilotus officinalis (L.) Pall.	Non-native

(Sheet 1 of 3)

Table 8 (Continued)

Species	Origin
Fagaceae	
Quercus lobata Nee.	Native
Quercus wislizenii A. DC	Native
Hippocastanaceae	
Aesculus californica Nutt.	Native
Juglandaceae	
Juglans californica S. Watson var. *hindsii* Jepson	Native
Juncaceae	
Juncus phaeocephalus Engelm. var. *paniculatus* Engelm	Native
Juncus spp.	Native
Lamiaceae	
Lycopus americanus W. C. Barton	Native
Mentha arvensis L.	Non-native
Lythraceae	
Ammannia coccinea Rottb.	Native
Malvaceae	
Malva sp.	Non-native
Onagraceae	
Epilobium glaberrimum Barbey	Native
Ludwigia peploides (Kunth) Raven	Native
Platanaceae	
Platanus racemosa Nutt.	Native
Poaceae	
Agropyron desertorum (Fischer) Schultes	Non-native
Avena fatua L.	Non-native
Bromus hordeaceus L.	Non-native
Echinochloa crusgalli (L.) P. Beauv.	Non-native
Leptochloa fasicularis (Lam.) A. Gray	Native
Lolium spp.	
Phalaris aquatica L.	Non-native
Phalaris tuberosa	Non-native
Phragmites australis (Cav.) Steudel	Global
Polygonaceae	
Polygonum argyrocoleon Kunze	Non-native
Polygonum hydropipeloides Michaux	Native
Polygonum lapathifolium L.	Native
Polygonum persicaria L.	Non-native
Rumex pulcher L.	Non-native
Primulaceae	
Samolus parviflorus Raf.	Native
Rosaceae	
Rosa spp.	

(Sheet 2 of 3)

Table 8 (Concluded)	
Species	**Origin**
Rubiaceae	
Cephalanthus occidentalis L. var. *californicus*	Native
Salicaceae	
Populus fremontii S. Watson	Native
Salix goodingii C. Ball	Native
Salix laevigata Bebb	Native
Salix lasiandra	Native
Salix lasiolepis Benth.	Native
Salix scoluriana Hook	Native
Solanaceae	
Solanum americanum Miller	Non-native
Solanum dulcamara L.	Non-native
Typhaceae	
Typha angustifolia L.	Native
Typha domingensis Pers.	Native
Typha latifolia L.	Native
Verbenaceae	
Verbena hastata L.	Native
	(Sheet 3 of 3)

species, the grassland (similar to the levees or upland areas at the mitigation site) contained 81.6 percent exotics, and the emergent vegetation contained 16.3 percent weedy species.

Willoughby and Davilla concluded that the primary reason for the low number of introduced species in the tidal streambank community is the restricted capability of introduced plants (most of which are annuals or non-rhizomatous perennials) to establish under conditions of periodic or prolonged inundation. In riprapped levees, the species in the inundated areas were primarily native.

Species which are frequently inundated are usually native. The upland herbaceous area is dominated almost exclusively by exotic species. The implications for succession, restoration, and mitigation are that the areas which are frequently submerged are primarily native. Provided that erosion does not unduly inhibit marsh establishment, one can reasonably expect to find the native complement of species commonly found in Central Valley emergent wetlands. At the Cache Slough mitigation site, species in areas with less disturbance through the erosive action of winds and waves have the highest species diversity.

Upland areas have little chance of succession to mature riparian forest without extensive management through irrigation after planting. Only 8 percent of the site was vegetated with woody vegetation in 1993. In 1992, severe

irrigation problems occurred. By 1993, a much higher survival rate occurred, the result of an irrigation system. In some areas, woody species have grown over 18 ft tall, and the structural diversity and aesthetic character of the site are beginning to metamorphose through the restoration process. Woody vegetation is naturally colonizing more stable areas of the site such as the north side. It is unknown from current monitoring data whether the site will be stable long enough to establish a mature riparian forest.

The woody species with the highest survival on the site are mule fat (*Baccharis vimineae*), California valley oak (*Quercus lobata*), California black walnut (*Juglans hindsii*), and Fremont cottonwood (*Populus fremontii*). Although there are a large number of California valley oak, their average height is less than 14 in. The other species grow much more rapidly, with mule fat averaging 82 in., California black walnut averaging 46 in., and Fremont cottonwood averaging 77 in. Natural revegetation is occurring in the wetted perimeter of the site, with a preponderance of willows and cottonwood.

Emergent vegetation is dominated by *Scirpus acutus, Cyperus eragrostis*, and *Typha* species. The west side of the site, leeward of prevailing winds, has the highest species diversity onsite (26 species) and is 70 percent vegetated. The south side of the site also has relatively high species diversity (19 species), but is only 50 percent vegetated due to higher erosion rates. Data from the 1993 field season indicate that the east side of the site, where prevailing wave and wind action cause high erosion rates and substrate instability, has only 11 species and is primarily unvegetated. In July 1994, revegetation has dramatically increased, with close to the entire area vegetated with emergent and woody plant species. Erosion control measures and replanting improved both planted species survival and natural revegetation. High August winds eroded some of this area, but a high percentage of the area was maintained. After installation of erosion-control measures and planting emergent and woody species, the area is revegetating. The north side of the site has 14 species and is 63-percent vegetative cover.

It is likely the remainder of the non-wetland component of the site will remain in weedy exotics. Dominant species for the herbaceous upland cover type include *Phalaris tuberosa*, *Avena fatua*, *Centaurea solstitialis*, and *Picris echioides*. Portions of the site are so densely vegetated with star thistle that the establishment of woody vegetation is unlikely. Other non-native species occurring in the upland area include Italian ryegrass, barnyard grass, white sweetclover, sweet fennel, artichoke, white clover, weedy cudweed, smooth cat's ear, bristly ox-tongue, prickly sow-thistle, bindweed, hedge mustard, perennial pepper-grass, and poison hemlock. The major succession sequence that may occur in the upland herbaceous area inside the basin is spread of blackberry and sweet fennel. Ox-tongue is outcompeting star thistle, and prickly lettuce appears to be reduced in abundance.

Reference Site

Thirty-four species were identified. Dominant species include *Scirpus acutus*, *Rubus* spp., *Ludwigia peploides*, *Salix scouleriana*, *Salix lasiandra*, *Polygonum lapathifolium*, *Salix* sp., and *Centaurea solstitialis*. These species comprise 83 percent of the relative abundance and 69 percent of the relative frequency. The transect represents a gradient comparable to the emergent area sampling in the mitigation site. Upland areas are dominated by star thistle (*Centaurea solstitialis*), ox-tongue (*Picris echioides*), ryegrass (*Lolium* sp.), reedgrass (*Phalaris tuberosa*), wild oats (*Avena fatua*), and prickly lettuce (*Lactuca serriola*). The wooded component borders the entire wetted perimeter and approximately 40 percent of the island. *Ludwigia peploides* occurs as an emergent in the open water area of the reference site. The island is dominated by tule (*Scirpus acutus* primarily) with dense wooded areas of willow and blackberry also occurring.

Multivariate analysis separated the upland component from the wetland component on the first axis, then the reference site from the mitigation site on the second axis. The major differences in species composition occur with the woody vegetation at the reference site. Over time, a percentage of the mitigation site will also include these woody species, but a much larger percentage of the site will include open water and non-native herbaceous upland species. Water quality and soils characteristics are similar between the two sites.

5 Lessons Learned and Recommendations

The results from this study of a riparian mitigation site point to a number of lessons learned during design and construction, and that can help serve as recommendations for construction of future western riparian sites. The problems of invasion of and dominance by exotic species into adjacent transition zones and uplands, dike instability, and overall ecological ambivalence in achieving forested wetland restoration can be addressed in a number of ways.

It is important first, however, to note that these problems should have been anticipated based on available historical data and information from local wetland experts in the field of western riparian habitats. For example, the mitigation design could have included a control and management scheme along with planting of the transition zones and uplands that would have hastened forested wetland succession and success on the site.

Observations indicate that the open water and emergent wetland portion of the Cache Slough mitigation site is currently receiving high use by fish and wildlife species. These types of habitats consist of over 81 percent of the mitigation project, and are providing high success. However, an important goal was forested wetland, and in the overall site, only 11 percent was planted as riparian habitats. Indications are that, given enough time, those planted species will dominate that portion of the site, especially the cottonwoods.

Overall site design should have allowed for elevations that would reforest, rather than remain in emergent marsh. The lesson learned here is to be sure that correct elevations and plantings to achieve the actual project goal are accomplished.

Dike stability required almost immediate repair, thus adding to the overall cost of the project. The lesson learned is to initially design and construct a dike that will remain stable for a long period of time. Forested wetland success on this site will require a long-term stable dike and also could have been anticipated in the overall design.

Natural sedimentation was planned to help raise the elevation and to increase the amount of forested wetland within the site. At the time this report

was completed, that process was ongoing, and over time, elevations will increase because of sediment trapping. This in turn will cause an increase in the amount of forested wetlands. The lesson learned here is not to promise short-term success on a habitat type (forested wetlands) that takes decades to achieve.

In all forested wetland restoration projects, patience is very important, as is the identification and establishment of long-term goals and objectives. The following is recommended for future western riparian restoration projects in the Central Valley (mitigation or nonregulatory):

a. Long-term goals and objectives be established to allow for the decades necessary for true mature forested wetlands to occur.

b. Designs stress site stability, since such habitats do require many years to develop.

c. Designs include sedimentation to achieve success in the overall design and site construction specifications to encourage appropriate elevations.

d. Exotic species temporarily controlled by mowing, by selected herbicides, or by the use of an appropriate herbaceous nurse crop that will not compete with small tree seedlings may be necessary to encourage the reforestation of the site by native riparian species of the Central Valley.

The heavy fish and wildlife use of the Cache Slough site makes it a very successful site as a shallow water/emergent wetland. Therefore, it is difficult to brand it a "failure." However, since the goal was forested riparian wetland, at least on the short-term, the site is not meeting expectations. Therefore, it is recommended that this mitigation site be revisited on a regularly scheduled basis to determine its long-range success as a forested riparian system. If it continues as an emergent marsh, and that is not considered satisfactory, mid-course corrections could be undertaken to raise the elevation to achieve riparian forest.

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Appendix A Emergent Vegetation Sampling

Transect #1

Transect #1, located on the north side of the mitigation area, was established August 31, 1992, and resampled July 20, 1993. Emergent vegetation constitutes a solid narrow band, planted by consultants in plugs. Rebar transects were established every 100 ft, following the landward bank at a compass reading of 28 deg. Every transect was measured to the waterward edge of the emergent vegetation to determine the extent of vegetation; this will allow determination of whether the marsh is building or eroding. One randomly placed quadrat was established in each transect.

Transect #2

Transect #2, located on the east side of the site, just north of the breach, was established on August 7, 1992, and resampled July 20, 1993. Four rebars were positioned peripheral to the emergent vegetation: one each on the north and south sides of the vegetation, one waterward and one landward. Three transects were then run from the landward stake: T-1 to the north stake, T-2 to the west or waterward stake, and T-3 to the south stake. Samples were taken every 5 ft. The length of each transect is recorded: T1 = 37.8 ft, T2 = 42.5 ft, T3 = 87.7 ft. Vegetation spread 44.7 ft north.

Transect #3

Transect #3, located south of the breach on the east side of the mitigation site, was established on September 16, 1992, and resampled July 15, 1993. Four transects were established similar to Transect #1. Four stakes of rebar were established at each site: one stake north, one stake south, one stake east, and one stake west. From the landward middle stake, the transects ran S11 to the north, S12 to the west, and S13 to the south. Total transect lengths were measured, as well as quadrats taken every 5 ft.

Transect #4

In Transect #4, emergent vegetation is measured in the southern portion of the site. Transect #4 was established on September 18, 1993. Since vegetation occurs in a long and narrow strip, transects are established similar to Transect #1. Transects are placed every 100 ft. Rebars are placed on the upland boundary, and the transect is established due north to the waterward edge of emergent vegetation. The total length of the transect is measured. Quadrats are taken every 5 ft.

Transect #5

In Transect #5, emergent vegetation in the northwest corner of the site south of the breach is measured. Transect #5 was established on September 21, 1992, and resampled July 27, 1993. Four rebar stakes were used: one north, one south, one east and one west. The transects were initiated at the landward or west rebar stake. SW1 is to the northern stake, SW2 is to the eastern stake, SW3 is to the southern stake. The emergent area grew considerably between 1992 and 1993. Therefore, the sampling design was changed. A series of short transects from the wetland/upland edge to the water were initiated on a compass reading of 90 deg from the landward side. Landward stakes are placed every 50 ft, with the first two transects every 58 ft. Quadrats begin in the upland and move toward the water. Transect length was #1 = 36.2 ft; #2 = 47 ft; #3 = 92.6 ft; #4 = 109.5 ft; #5 = 44 ft; #6 = 41 ft; #7 = 43 ft; #8 = 32 ft; #9 = 27 ft; #10 = 81 ft; #11 = 81 ft.

Transect #6

Transect #6 is located on the eastern portion of the site south of the breach and south of Transect #3. This transect is in the southeast corner of the site. It was established July 15, 1993. Four rebars and three transects were initiated: #1 south, #2 middle, #3 north.

Appendix B
Geology

The Sacramento-San Joaquin Delta is an area of over 830 square miles where the distributaries and floodplains of the Sacramento and San Joaquin Rivers overlap the reach of tidal effects transmitted to the interior through the greater San Francisco Bay system (Thompson 1982). This estuarine condition of the delta has persisted through some 8,000 to 10,000 years of post-Pleistocene rise in sea level, which has favored the formation of peat. In general, sediment deposition during the past million years occurred during alternate cycles of deposition and erosion.

The delta consists of a very large area of peat with mantling marsh vegetation at or near sea level, hundreds of miles of channels and sloughs, and, between marsh and channels, the natural levees that are the product of the natural deposition of sediment during flood stages. In the central delta these natural rims are only a foot or two above mean sea level, but the natural levees of the master channels gradually become higher headward, reaching elevations exceeding 10 ft.

The study area is mapped as basin deposits, including peat and organic soils (Atwater 1980):

> The flood-basin deposits are firm to stiff (unconfined shear strength 2-4 kg/cm^2 by pocket penetrometer) silty clay, clayey silt, and silt, commonly with $CaCO_3$ nodules and locally with clack, slightly metallic, fine-sand to granule-size spherules (Mn and or Fe oxides). Colors are very dark gray (10 YR 3/1) to dark gray (N 6/0), locally variegated and mottled in hues of 5Y to 7.5YR. The deposits formed in supratidal reaches of basins flanking the Sacramento River and in interdistributary basins not necessarily above high-tide levels but probably cordoned off from tidal waters by supratidal natural levees. Natural vegetation was dominated by *Scirpus acutus*. The deposits grade laterally into peaty mud and mud of tidal wetlands of Yolo Basin, Sutter Island, and Peirson District. Contacts with tidal-wetland deposits in cores are locally abrupt but commonly grade through mud that forms angular aggregates 0.1 to 2.0 mm in diameter, a granular structure attributable to occasional

desiccation. Locally the deposits are veneered with silty, reddish brown alluvium of historic age.

The natural sedimentation rate in late Holocene time...is less than rate of relative sea-level rise in San Francisco Bay but not inconsistent with the possibility that rise in base level caused much of the late Holocene aggradation in near-sea-level flood basins of the Sacramento River. The unit was historically mapped as Sacramento and Columbia-over Sacramento soils.

Appendix C
Soils

The soils throughout the project area are mapped as the Egbert series in the Solano County soil survey (Appendix B) (U.S. Department of Agriculture Soil Conservation Service 1972). The Egbert series consists of level to nearly level, poorly drained soils in basins. These soils formed in alluvium derived from mixed sources. Where these soils are not cultivated, the vegetation is annual grasses and forbs. The average annual temperature is 60 to 62 °F, the average annual rainfall is 16 to 18 in., and the frost-free season is 260 to 280 days. Elevation ranges from 5 ft below sea level to 10 ft above sea level.

In a representative profile, the surface layer is gray silty clay loam 31 in. thick. The substratum is mottled, gray silty clay loam that extends to a depth of more than 60 in.

Permeability is moderately slow in the subsoil. Effective rooting depth is more than 60 in. Available water capacity is 10 to 12 in. where these soils are drained. The water table is maintained at depth of 48 to 60 in.

Egbert soils are used for irrigated row crops, field crops, dryfarmed grain, wildlife habitat, and recreation.

A representative profile of Egbert silty clay loam is as follows:

a. Ap - 0 to 6 in., gray (10 YR 5/1) silty clay loam; few, fine, distinct, yellowish-brown (10 YR 5/4) mottles; very dark gray (10 YR 3/1) when moist; moderate, medium, and coarse, granular structure; very hard, firm, sticky, plastic; many very fine and fine roots; common very fine tubular pores and many very fine interstitial pores; slightly acid; clear, smooth boundary.

b. A1 - 6 to 31 in., gray (10 YR 5/1) silty clay loam, very dark gray (10 YR 3/1) when moist; strong, very coarse, prismatic structure; very hard, firm, sticky, plastic; many very fine roots; common very fine and fine tubular pores; medium acid; gradual, wavy boundary.

c. B2g - 30 to 45 in., gray (10 YR 6/1) silty clay loam that has common, fine, prominent, brown (7.5 YR 5/4) and grayish-brown (2.5 Y 5/2) mottles; very dark gray (10 YR 3/1) and has common, fine, prominent, dark-brown (7.5 YR 4/4) and dark, grayish-brown (2.5 Y 4/2) mottles when moist; moderate, very coarse, prismatic structure; very hard, very firm, sticky, plastic; many very fine and fine pores and few medium pores; medium acid; diffuse, smooth boundary.

d. Cg - 45 to 60 in., gray (5 Y 6/1) silty clay loam that has many, large, prominent, reddish-yellow (7.5 YR 6/6) mottles; dark gray (5 Y 4/1) and has many, large, prominent, dark-brown (7.5 YR 4/4) mottles when moist; moderate, very coarse, prismatic structure; very hard, firm, sticky, plastic; many very fine roots; common very fine and fine tubular pores; medium acid.

e. The A horizon ranges from gray to dark gray in color and from silty clay loam to heavy clay loam in texture. The A horizon is 8 to 31 in. thick. The B2g horizon ranges from gray to light gray in color and from silty clay loam to heavy clay loam in texture. Reaction is slightly acid to medium acid. Thickness is 12 to 20 in. The C horizon ranges from gray to light gray in color and from silty clay loam to heavy clay loam in texture. Reaction is slightly acid to medium acid.

This nearly level soil is in basins. It has the profile described as representative for the series. Included with this soil in mapping are small areas of Sacramento clay, Ryde clay loam, and Omni silty clay.

The naturally poor drainage of this soil has been improved by leveling, using open drains, and pumping so that the water table remains at a depth of 4 to 5 ft. Runoff is very slow; erosion is not a hazard.

This soil is used mostly for irrigated sugar beets, tomatoes, corn, alfalfa, and grain sorghum. It is also used for dryfarmed barley, safflower, wildlife habitat, and recreation.

Appendix D
Natural Communities of California

Riparian Forests — Great Valley Riparian Forest

Description

A dense, broadleafed, winter deciduous riparian forest dominated by *Populus fremontii* and *Salix goodingii variabilis*. Understories are dense, with abundant vegetative reproduction of canopy dominants. *Vitis californica* is the most conspicuous liana. Scattered seedlings and saplings of shade-tolerant species such as *Acer negundo californica* or *Fraxinus latifolia* may be found, but frequent flooding prevents their reaching into the canopy.

Site factors

Fine-grained alluvial soils near perennial or nearly perennial streams that provide subsurface irrigation even when the channel is dry. These sites are inundated nearly every spring, resulting in the annual input of nutrients, soil, and new germination sites. There are intergrades at sites higher and farther from the river with Great Valley Mixed Riparian Forest and Great Valley Willow Scrub on sites closer to the river that are subject to more severe flooding disturbance.

Characteristic species

Acer negundo californica, Cephalanthus occidentalis, Elymus triticoides, Fraxinus latifolia, Populus fremontii, Salix goodingii variabilis, S. hindsiana, S. laevigata, S. lasiandra, S. lasiolepis, Vitis californica.

Distribution

Formerly extensive along the major low-gradient (depositional) streams throughout the Great Valley, but now reduced to scattered, isolated remnants or young stands because of flood control, water diversion, agricultural development, and urban expansion; typically below about 1,000 ft in the north, 300 ft in the south.

Sources

Roberts, Howe and Major (1980); Sands (1980); Thompson (1957); Conrad, MacDonald, and Holland (1976); Holstein (1984).

Riparian Forest — Great Valley Mixed Riparian Forest

Description

This is a tall, dense, winter-deciduous, broadleafed riparian forest. The tree canopy usually is fairly well closed and moderately to densely stocked with several species including *Acer negundo californica, Juglans hindsii, Platanus racemosa, Populus fremontii, Salix goodingii variabilis, S. laevigata*, and *S. lasiandra.* Understories consist of these taxa plus shade-tolerant shrubs like *Cephalanthus occidentalis* and *Fraxinus latifolia.* Several lianas are conspicuous in both tree and shrub canopies.

Site factors

Relatively fine-textured alluvium is somewhat back from active river channels. These sites experience overbank flooding (with abundant alluvial deposition and groundwater recharge) but not too severe physical battering or erosion. Intergrades are closer to the river with Great Valley Cottonwood Riparian Forest where disturbance is both more frequent and more severe; intergrades are farther away from the river with Great Valley Oak Riparian Forest where such disturbance is less.

Characteristic species

Acer negundo californica, Cephalanthus occidentalis, Clematis ligusticifolia, Juglans hindsii, Platanus racemosa, Populus fremontii, Salix goodingii variabilis, S. laevigata, S. lasiandra, Toxicodendron diversilobum, Vitis californica.

Distribution

Floodplains of low-gradient, depositional streams of the Great Valley are usually below about 500 ft. Formerly very extensive in the Sacramento and northern San Joaquin Valleys, this forest largely has been cleared for agriculture, flood control, and urban expansion.

Sources

Roberts, Howe and Major (1980); Thompson (1957); Conrad, MacDonald and Holland (1976); Holstein (1984); Katibah, Dummer, and Nedeff (1984); Warner (1984).

Great Valley Willow Scrub

Description

This is open to dense, broadleafed, winter-deciduous shrubby streamside thicket dominated by any of several *Salix* species. Dense stands usually have little understory of a herbaceous component. More open stands have grassy understories, usually dominated by introduced species.

Characteristic species

Bromus diandrus, *Chenopodium abrosioides*, *Cynodon dactylon*, *Populus fremontii*, *Rosa californica*, *Salix hindsiana*, *S. lasiandra*, *S. lasiolepis*, *S. melanopsis*, *Vitis californica.*

Distribution

The thicket is along all the major rivers and most of the smaller streams throughout the Great Valley watershed, usually below 1,000 ft.

Sources

Montroni (1979), (1984).

Coastal and Valley Freshwater Marsh

Description

The area is dominated by perennial, emergent monocots 4 to 5 m tall. They often form completely closed canopies. *Scirpus* and *Typha* dominated types, and their environmental and floristic distinctions require clarification.

Site factors

These sites are quiet (lacking significant current), permanently flooded by fresh water (rather than brackish, alkaline, or variable). Prolonged saturation permits accumulation of deep, peaty soils.

Characteristic species

Carex lanuginosa, C. senta, C. eragrostis, Eleocharis sp., *Hydrocotyl verticillata triradiata, Limosella aquatica, Phragmites australis, Scirpus acutus, S. americanus, S. californicus, S. robustus, Sparganium eurycarpum, Typha angustifolia, T. domingensis, T. latifolia, Verbena bonariensis.*

Distribution

Marsh is occasional along the coast and in coastal valleys near river mouths and along the margins of lakes and springs. It is most extensive in the upper portion of the Sacramento-San Joaquin River Delta. It is common in the Sacramento and San Joaquin Valleys in river oxbows and other areas on the floodplain and occasional along the Colorado River on the California-Arizona border. Now it is much reduced in area through its entire range.

Sources

Conrad, MacDonald, and Holland (1976); Warner (1984); Roberts, Howe, and Major (1980); Thompson (1957); Holstein (1984); Katibah, Dummer, and Nedeff (1984).

Appendix E
Species of Concern

California Hibiscus (*Hibiscus californicus*)

The California hibiscus is a candidate species for Federal listing. At the State level, the species is afforded protection under Section 1901, Chapter 10 (Native Plant Protection), of the California Fish and Game Code and is eligible for State listing.

The plant is associated with moist freshwater-soaked river banks and low peat islands of the lower Sacramento and San Joaquin Rivers. Although California hibiscus is generally not expected to occur in rip-rapped slopes, it has been found under these habitat conditions (California Natural Diversity Data Base 1990). Surveys of the levee in the project area were negative.

Delta Tule Pea (*Lathyrus jepsonii* spp. *jepsonii*)

The Delta tule pea is a candidate species for Federal listing. At the State level, the species is afforded protection under Section 1901, Chapter 10 (Native Plant Protection), of the California Fish and Game Code and is eligible for State listing.

Mudflat Quill (*Lilaeopsis masonii*)

The mudflat quill is a candidate species for Federal listing and a State-listed Rare plant. It can be found growing on sandy margins, clay-peat deposits, decaying woody debris and on sediment deposits where the plant is frequently inundated by waves. The primary endangerment factors to the species are from man-caused alterations of its habitat. The plant is known to occur throughout the region along the shoreline of the Sacramento River.

Suisun Marsh Aster (*Aster chilensis* var. *lentus*)

The Suisun marsh aster is a candidate species for Federal listing. At the State level, the species is afforded protection under Section 1901, Chapter 10 (Native Plant Protection), of the California Fish and Game Code and eligible for State listing.

This plant is known to grow along tidal streams and in marshy areas of the delta and Suisun Bay.

Antioch Dunes Evening Primrose (*Oenothera deltoides*)

This plant is associated with loose sand and stabilized dunes along the margins of the San Joaquin River near Antioch.

Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*)

The valley elderberry longhorn beetle is a Federally listed threatened species. It is endemic to riparian woodlands along the margins of rivers and streams in the lower Sacramento River and Upper San Joaquin Valleys. The beetle is a wood-boring insect that is dependent on the elderberry (*Sambucus* sp.) as its host plant and completes its life cycle within 2 years. The larvae tunnel and feed inside the elderberry plant until they pupate and emerge as adults. The adults feed on the new foliage of terminal leaves and the pollen of flower heads and are most readily observed between late April and mid May.

The extensive loss of riparian habitat which supported elderberry stands and savannahs is considered the primary cause for reduction in the beetle's distribution.

Sacramento Anthicid Beetle (*Anthicus Sacramento*)

The beetle is known to use dry sand dune areas on the Sacramento River.

Tricolored Blackbird (*Agelaius tricolor*)

The tricolored blackbird is a candidate species for Federal listing and a State Species of Special Concern. A California endemic, the tricolored

blackbird's range is primarily in the interior valleys west of the Sierra Nevada. It breeds in the Central Valley, along the coast from Sonoma County south, and on the Modoc Plateau south to Honey Lake, Lassen County. Loss of suitable wetland and riparian habitat, aerial spraying, and nest disturbance have been cited as the probable causes of decline in its population.

This species nests in colonies adjacent to brackish and freshwater marshes that support heavy growth of cattails, or in dense thickets of willows, thistles, mustard, or blackberry bushes. There is a possibility that the mitigation site could be used by the tricolored blackbird, but none have yet been cited. Beedy et al. (1991) feels there may not be an adequate food base (insect supply) in the area to support a large colony.

Willow Flycatcher (*Empidonax traillii*)

The willow flycatcher is a State-endangered and a Federal-sensitive species. Willow flycatchers inhabit wet meadows which are 10 acres or more in size and have tall, dense thickets or willows. This species is likely to occur only in the reference area or the riparian islands off the site.

Swainson's Hawk (*Buteo swainsonii*)

Swainson's hawk is a candidate species for Federal listing and a State-listed Threatened species. It typically nests in oak, cottonwood, and eucalyptus trees in the Central Valley in or near riparian areas with grassland for foraging. Trees of suitable size and kind for nesting occur offsite. Several Swainson's hawks (as many as 13 at one time) were cited regularly just north of the mitigation site in the fall.

California Black Rail (*Laterallus jamaicensis coturniculus*)

The California black rail is a State Threatened species and a Federal candidate for listing. The California Black Rail once bred in marshes of the San Francisco Bay and the Sacramento-San Joaquin Delta. With the destruction of coastal marshes, damming, and channelization, habitat for this species has decreased. Potential habitat within the mitigation area is minimal.

Winter Chinook Salmon (*Oncorhynchus tschawtscha*)

The winter run chinook salmon is a Federally listed Threatened species and a State-listed Endangered species. The winter chinook is considered racially distinct from all other runs of chinook salmon. Once endemic to the Sacramento, the McCloud, and the lower Pit Rivers, Keswick Dam now represents the upstream limit of the chinook's distribution. Spawning now occurs only immediately below the dam. In addition to this loss of historical habitat, other contributing factors have led to species decline. These include water pollution from agricultural and industrial sources, toxic wastes, and channelization and bank stabilization along the Sacramento River.

Sacramento Splittail (*Pogonichtys macrolepidotus*)

The splittail is a candidate for Federal listing and a State Species of Special Concern. Its declining population status warrants special management to prevent it from becoming a Threatened species. This large native minnow is endemic to the lakes and rivers of the Central Valley of California. The disappearance of the splittail from much of its native range is largely attributable to water development and reclamation projects which have eliminated or drastically altered habitat the fish once occupied.

This species can be expected to occur within the Sacramento River in the vicinity of the mitigation site. Spawning in the upper delta generally occurs during March and April along the slower moving reaches of rivers and sloughs where flooded vegetation is available. The aquatic vegetation provides both a spawning substrate and, later, nursery habitat for larvae. Young fish move into deeper offshore habitat later in summer. There is a potential for splittail utilizing the mitigation site for spawning and rearing habitat.

Delta Smelt (*Hypomesus transpacificus*)

The delta smelt has been listed as Threatened under the Endangered Species Act this year and is a State species of Special Concern. Considered one of the most common fish in the delta as recently as the 1970's, it has undergone a tenfold decline in the past 20 years (from 2.6 million to an estimated 280,000). There are a number of contributing factors responsible for the species population decline, including reduced delta outflows, changes in food organisms, destruction of habitat, water pollution, and entrainment losses to water diversions.

The delta smelt schools in large numbers in the open surface waters of the delta. They concentrate in the delta's lower reaches during the months of September to November. Most spawning takes place between February and June in dead-end sloughs and along shallow edgewaters of the upper delta and the Sacramento River above Rio Vista. The eggs are adhesive, attaching to submerged vegetation, rock, and gravel. After an approximate 2-week incubation period, the eggs hatch and the larvae are washed downstream until they reach the mixing zone where the fish remain to grow to maturity.

The outlook for the future of the delta smelt is grim. Its currently low population status, 1-year lifespan, and low fecundity leave the species susceptible to extinction in the event of a total spawning failure during 1 year. The mitigation site has provided spawning habitat for delta smelt for the past 2 years. Further sampling will be occurring in the mitigation site and adjacent area.[1] Results of sampling conducted by the U.S. Fish and Wildlife Service will be included in future annual reports.

California Tiger Salamander (*Ambystoma tigrinum californiense*)

The California tiger salamander is a Candidate for Federal listing and a State species of Special Concern. It may be found in riparian and wet meadow habitat but is more common in grasslands. Extensive agricultural development of the area adjacent to the mitigation site renders potential habitat for the salamander doubtful.

Giant Garter Snake (*Thamnophis couchi gigas*)

The giant garter snake is a State Threatened species and a candidate for Federal listing. It inhabits freshwater ponds and sloughs in areas with dense emergent vegetation. Primary foods are fish and amphibian larvae. Historically the snake has been observed in the area, although with the continuous cleaning of slough vegetation, the habitat is declining.

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1 Personal Communication, 1993, Mike Fris, U.S. Fish and Wildlife Service, Sacramento, CA.

Appendix F
Permanent Photo Stations

Figure F1. Northeast corner of site facing south (View of emergent vegetation, open-water, and upland-herbaceous cover types. The east island is visible.)

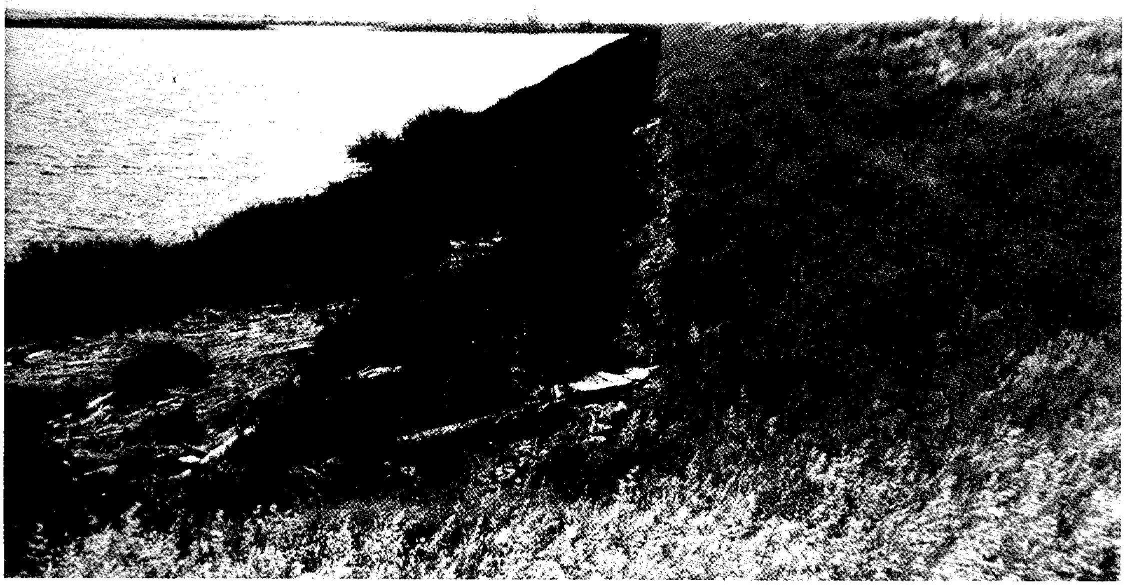

Figure F2. Northeast corner of site facing west (View of emergent vegetation, open-water, and upland-herbaceous cover types. The west breach is visible. Accumulation of flotsam and jetsam is clearly visible.)

Figure F3. West breach facing west (A clear view of the northwest corner of the site and the west breach.)

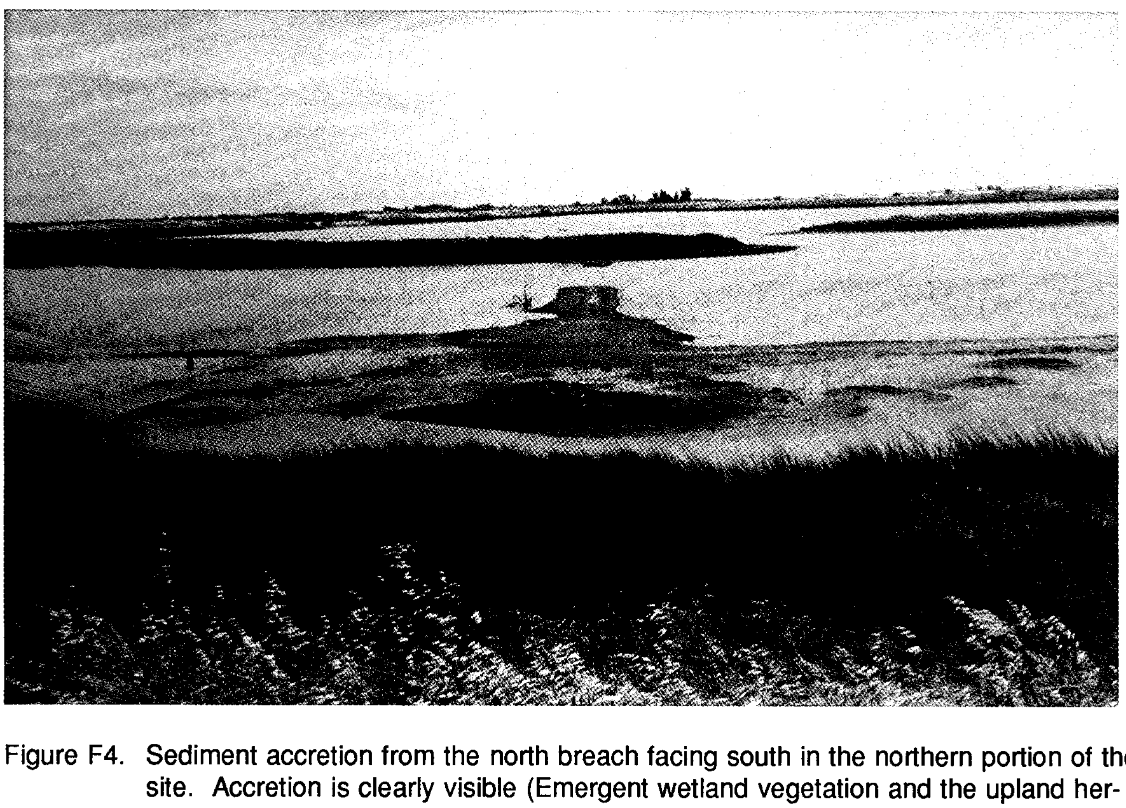

Figure F4. Sediment accretion from the north breach facing south in the northern portion of the site. Accretion is clearly visible (Emergent wetland vegetation and the upland herbaceous vegetation on the two islands are also visible.)

Northwest corner facing east. Cross levee plantings

Northwest corner facing southwest

Figure F5. Northwest corner facing south (Sediment accretion is also clearly visible in this section of the mitigation site. Planted riparian woody vegetation is doing quite well in this area, with some of the cottonwoods over 18 ft tall. Original trees planted when the farmhouse was on the site have drowned.)

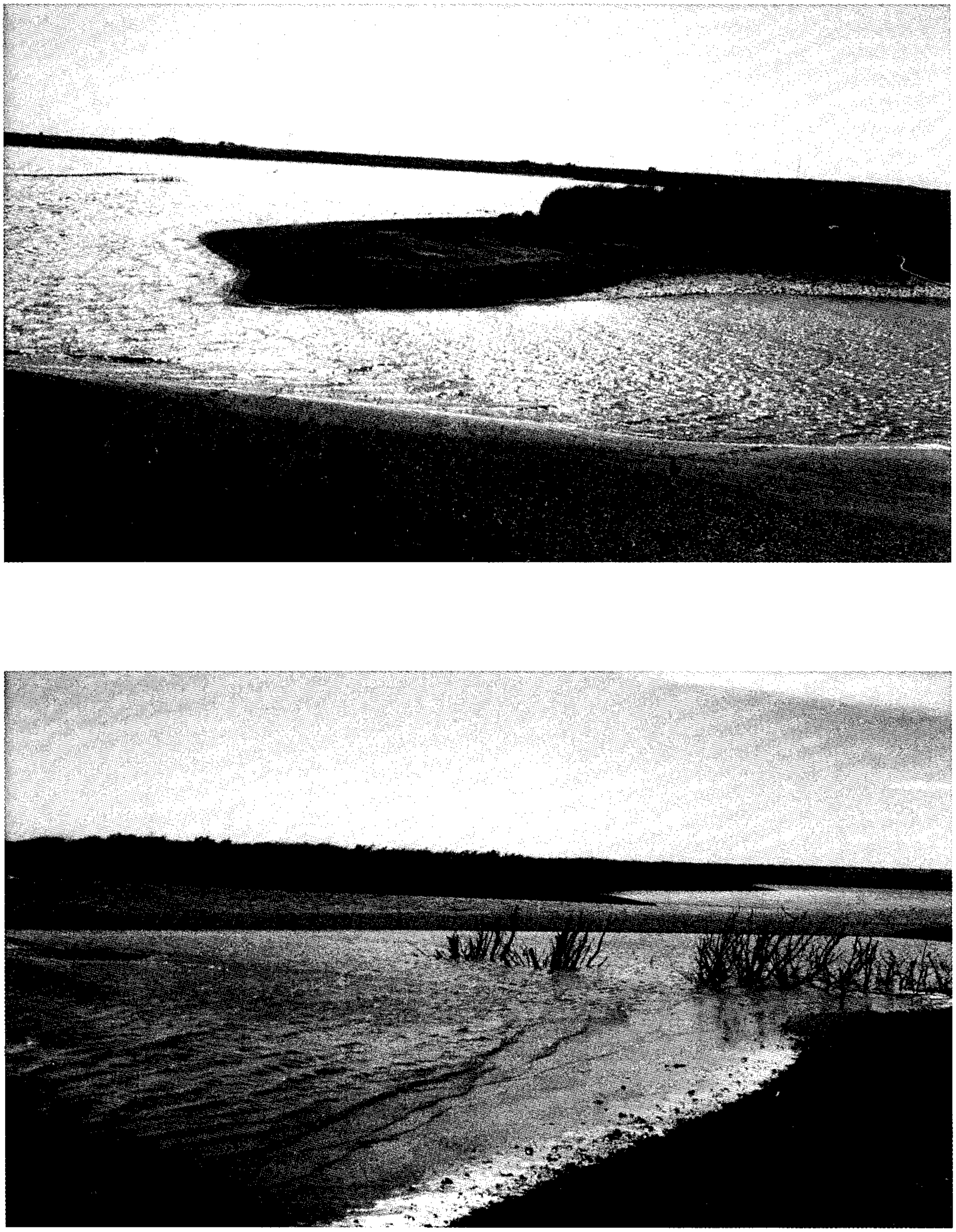

Figure F6. Point bar formation on the leeward side of the eastern island (Sediment is accreting on the lee side of the island.)

Figure F7. East breach facing south (Upland herbaceous cover type clearly visible. High winds and whitecaps are typical for mid to late summer, blowing from west to east.)

Figure F8. Erosion control measures implemented on the west side of the site above the east breach (High summer winds, long fetch, and waves resulted in significant erosion the first year. After implementation of erosion control measures in 1993 and 1994, emergent vegetation and planted woody vegetation began to stabilize the shoreline and levees.)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1995	Final report

4. TITLE AND SUBTITLE
Cache Slough/Yolo Bypass Ecosystem Monitoring Study to Determine Wetland Mitigation Success

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of California, Davis
Botany Department
Davis, CA 95616

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000;
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Technical Report
WRP-RE-11

11. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report provides monitoring data on the Cache Slough/Yolo Bypass mitigation area. The area was designed and constructed by the Corps of Engineers to function as a mitigation bank to provide mitigation for impacts to fish and wildlife habitats from the Sacramento River Bank Protection Project. The mitigation area includes approximately 9,000 lin ft (approximately 38 acres) of bypassed levee and a 138-acre interior basin area of primarily open water. The Cache Slough site is located west of the Sacramento River in the northern area of the Sacramento-San Joaquin Delta.

This study was designed to monitor mitigation success in relation to project goals and objectives, in comparison to adjacent reference areas. Eight permanent transects with associated permanent vegetation quadrats were established around the perimeter of the open-water component of the mitigation area. Species composition, relative abundance, and frequency were measured. Results indicated that native vegetation along the levees is representative of the delta and includes the following: willows (*Salix goodingii, S. lasiolepis*), elderberry (*Sambucus* sp.), black walnut (*Juglans hindsii*), valley oak (*Quercus lobata*), interior live oak (*Quercus wizliwenii*), white alder (*Alnus rhombifolia*), cottonwood (*Populus fremontii*), hard-stem bulrush (*Scirpus acutus*), cattail (*Typha* spp.) and horse tail

(Continued)

14. SUBJECT TERMS
Habitat
Mitigation
Monitoring
Western riparian
Wetlands

15. NUMBER OF PAGES
100

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

13. (Concluded).

(*Equisetum* spp.). Prevalent non-native species include blackberry (*Rubus* spp.), artichoke (*Cynara scolmus*), and sweet fennel (*Foeniculum vulgare*). Eighty-seven percent of the site is dominated by non-native species.

Aerial photographs were obtained and field truthed by walking around the site and delineating woody vegetation on the photograph. Results indicated that cover types on the site are open water (125.67 acres), riparian cover (13.45 acres), emergent wetland vegetation (9.54 acres), upland shrub and herbacious (19.11 acres), two upland islands (6.69 acres), upland road and parking (0.95 acre), riprap (0.48 acre), and cross levee (5.55 acres). Total acreage with cross levee is 181.44.

Soil samples were collected and analyzed for calcium, magnesium, sodium, chlorine, sulfate, total nitrogen, percent organic matter, and soil texture. Sediment budget data were also collected to qualify sediment input and output on an average tidal cycle. Piezometers were installed to take measurements of surface and interstitial groundwater in both reference and mitigation sites. One-liter composite water samples were taken throughout the year where piezometers were located and analyzed for nutrients, including ammonium, nitrogen, and total phosphorus.